

UNCLASSIFIED

AD NUMBER

AD866350

NEW LIMITATION CHANGE

TO

Approved for public release, distribution  
unlimited

FROM

Distribution authorized to U.S. Gov't.  
agencies and their contractors; Critical  
Technology; NOV 1969. Other requests shall  
be referred to Commander, Naval Ships  
Command, Attn: SHIPS 03424, Washington,  
DC.

AUTHORITY

USNSEC ltr, 15 Aug 1973

THIS PAGE IS UNCLASSIFIED

JRC

IMPORTANT NOTICE

Those portions of this report which are intended exclusively for the information of the Department of Defense agencies are contained in blue removable pages and should be deleted before release to private organizations or individuals.

NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER  
Washington, D. C. 20007

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY  
Annapolis, Maryland 21402

100-866350  
AM  
HANDBOOK OF  
FLUIDS AND LUBRICANTS  
FOR  
DEEP OCEAN APPLICATIONS

D D C  
R P A R M R P D  
R E C U L T U R E D  
MAR 24 1970  
JRC

STATEMENT #4 UNCLASSIFIED

Each transmittal of this document outside the Department of Defense must have prior approval of ~~Naval Ship Systems~~  
Command. SHIPS-03424, Wash DC 20360

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Commander, Naval Ship Systems Command (SHIPS 03424), Washington, D. C. 20360

**Best  
Available  
Copy**

HANDBOOK OF FLUIDS AND LUBRICANTS  
FOR  
DEEP OCEAN APPLICATIONS

Compiled and Edited by

Richard W. McQuaid and Charles L. Brown  
Naval Ship Research and Development Laboratory  
Annapolis, Maryland

Based on the Research and Development Effort of the Following  
Scientists and Engineers of the Naval Ship Research and  
Development Laboratory, Annapolis:

D. L. Bloomquist	J. A. Marzani
C. L. Brown	T. D. Morrison
W. E. Chaffee*	O. L. Mitchell*
R. F. Codd	W. Philippoff**
T. N. Cornish	W. E. Pocock
R. J. Flaherty, Jr.	A. F. Rehn
C. W. Kellenbenz	P. Schatzberg
R. K. Lebowitz	J. F. Tobin
J. C. Limpert	D. R. Ventriglio
C. C. Lumpkin	

\*Materials Laboratory, San Francisco Bay Naval Shipyard,  
Vallejo, California.

\*\*Esso Research and Engineering Company, Linden, New Jersey,  
under Contract No. N00161-68-00458 with Naval Ship Research  
and Development Laboratory, Annapolis, Maryland

## ABSTRACT

The critical factors involved in the selection of fluids and lubricants for deep ocean equipment are defined, and methods of determining critical properties are described. The values of critical properties are given for fluids and lubricants as they have been determined or are known from previous literature. Suggestions also are given on the applicability and possible limitations of the fluids and lubricants for deep submergence vehicle use. It is planned to revise and update the contents of this handbook periodically.

## PREFACE

The Deep Ocean Technology (DOT) "Handbook of Fluids and Lubricants for Deep Ocean Applications" was prepared to provide critical properties, evaluation methods, and other pertinent fluid and lubricant information to designers, engineers, and operating personnel concerned with deep ocean applications.

This handbook is a "guide," not a specification. It cannot be cited as authority for action. It supplements published information and aids the user in selection of a fluid or lubricant applicable to a particular deep ocean application.

### Content and Organization of the Handbook

Chapter I defines and discusses the factors involved in the selection and performance of fluids and lubricants in deep ocean applications. This chapter is written as an integrated account to be read in sequence as in a book.

Chapter II describes in detail the methods employed for establishing the fluid properties presented in Chapter III. This last chapter provides suggested applications and possible limitations in addition to the properties.

In compiling these data we have consulted many sources and utilized applicable experience wherever found. Thus, the Bibliography represents, in effect, contributors as well as source material.

### Revisions, Growth, and "User Comment Return Form"

The DOT "Handbook of Fluids and Lubricants for Deep Ocean Applications" is designed to be periodically revised to include new data and considerations for fluid encapsulated system design and additional deep ocean applications. Responsibility for the maintenance and expansion of the handbook has been assigned, under the supervision of the Naval Ship Systems Command (SHIPS 03424), to the Naval Ship Research and Development Laboratory, Annapolis, Maryland.

Revisions to the handbook will be effected by the use of page changes and additions. As the handbook is published in loose-leaf form, revisions may easily be made.

PREFACE (Cont)

Using commands and individuals within the Navy and the non-military marine community are encouraged to submit additional data, paragraphs, or chapters. Less extensive feedback - even mere indications that specified sections are judged to be too general - is useful and solicited. Feedback may be forwarded directly to

Deep Ocean Technology Program  
Naval Ship Research and Development Laboratory  
Annapolis, Maryland 21402

Material received will be carefully reviewed and coordinated prior to publication. A handy preaddressed user comment return form is included for your convenience.

## ADMINISTRATIVE INFORMATION

This first edition of the handbook was begun by the Naval Ship Research and Development Laboratory, Annapolis, Maryland, as part of the Deep Ocean Technology Program, S4636, Task 12315, Work Unit 1-821-118-A "Fluids and Lubricants for Deep Submergence Applications." The Program Manager was the Naval Ship Systems Command (SHIPS 03424), and Naval Ship Engineering Center (SEC 6101F) was the Technical Agent. It was completed under S4636, Task 14745, Laboratory Work Unit 1-723-113-A, "DOT Compensating Systems." The Program Manager was Naval Ship Systems Command (SHIPS 03424), and Naval Ship Engineering Center (SEC 6141) was the Technical Agent.

**IDENTIFICATION OF FLUID CODES**

Fluid Code	Commercial Name	Supplier
A	PR-1192	E. F. Houghton Co., 303 W. Lehigh Ave., Philadelphia, Pa. 19133
B	Micronic 713	Bray Oil Co., 3344 Medford St., Los Angeles, Calif. 90063
C	Micronic 762	Bray Oil Co., 3344 Medford St., Los Angeles, Calif. 90063
D	NDH-TD4-1	New Departure - Hyatt Bearings, Hayes Ave., Sandusky, Ohio 44871
E	Hoover Submersible Fluid No. 2	Hoover Electric Co., 2100 South Stoner St., Los Angeles, Calif. 90025
F	Tellus 11	Shell Oil Co., 50 W. 50th St., New York, N. Y. 10020
G	Tellus 15	Shell Oil Co., 50 W. 50th St., New York, N. Y. 10020
H	Tellus 27	Shell Oil Co., 50 W. 50th St., New York, N. Y. 10020
J	Primal 207	Humble Oil and Refining Co., P.O. Box 1288, Baltimore, Md. 21203
K	Narcol 52	Humble Oil and Refining Co., P.O. Box 1288, Baltimore, Md. 21203
L	SF-1143	General Electric Co., Silicone Products Dept., Waterford, N.Y. 12188
M	C-141	Royal Lubricants Co., River Rd., Hanover, N. J. 07936
N	PR-85-29-129	E. F. Houghton Co., 303 W. Lehigh Ave., Philadelphia, Pa. 19133

via

## TABLE OF CONTENTS

	<u>Page</u>
<b>ABSTRACT</b>	iii
<b>PREFACE</b>	iv
<b>ADMINISTRATIVE INFORMATION</b>	vi
<b>INTRODUCTION</b>	ix
<b>CHAPTER I - FLUID AND LUBRICANT PROPERTIES AND USE CLASSIFICATION</b>	I-1
<b>CHAPTER II - METHODS FOR ESTABLISHING FLUID PROPERTIES</b>	II-1
<b>CHAPTER III - FLUID AND LUBRICANT PROPERTY VALUES, APPLICATIONS AND LIMITATIONS</b>	III-1
<b>Federal Specification Products</b>	III-5
<b>    VV-I-530a</b>	III-6
<b>    VV-D-001073 (10 CS)</b>	III-12
<b>    VV-D-001078 (50 CS)</b>	III-18
<b>Military Specification Products</b>	III-25
<b>    MIL-H-5606B</b>	III-26
<b>    MIL-J-5624F</b>	III-32
<b>    MIL-L-6081C, Grade 1010</b>	III-37
<b>    MIL-L-6083C</b>	III-43
<b>    MIL-L-6085A</b>	III-49
<b>    MIL-L-7808G</b>	III-55
<b>    MIL-L-7870A</b>	III-61
<b>    MIL-C-8188C</b>	III-67
<b>    MIL-F-17111</b>	III-73
<b>    MIL-L-17672, MS 2110-TH</b>	III-79
<b>    MIL-S-21568A</b>	III-85
<b>    MIL-L-23699A</b>	III-90
<b>    MIL-H-27601A</b>	III-96
<b>    MIL-H-46004</b>	III-102
<b>    MIL-H-81019B</b>	III-108
<b>Proprietary Fluids</b>	III-115
<b>    Fluid Code A</b>	III-116
<b>    Fluid Code B</b>	III-122
<b>    Fluid Code C</b>	III-127
<b>    Fluid Code D</b>	III-132
<b>    Fluid Code E</b>	III-137
<b>    Fluid Code F</b>	III-142

TABLE OF CONTENTS (Cont)

	<u>Page</u>
Fluid Code G	III-147
Fluid Code H	III-152
Fluid Code J	III-157
Fluid Code K	III-162
Fluid Code L	III-167
Fluid Code M	III-172
Fluid Code N	III-177
<b>BIBLIOGRAPHY</b>	<b>B-1</b>
<b>USER COMMENT RETURN FORM</b>	
<b>DISTRIBUTION LIST</b>	

## INTRODUCTION

In the typical U. S. Navy submarine, most of the operating machinery for propulsion, maneuvering, and other required functions is located within the pressure hull. In contrast, only the control equipment of deep submergence vehicles is housed within the pressure capsule. It is connected by wires through glass-to-metal seals through the capsule to external machinery. Thus, only electrical control signals are provided to pumps, motors, winches, hydraulic systems, and the other required machinery operating in the ambient pressure, temperature, and contaminants of the deep ocean.

To shield system components from the corrosive action of seawater and other effects of the ocean environment requires that equipment be operated within some sort of protective medium. Three approaches are being pursued: (1) encapsulation, (2) the "hard shell," and (3) fluid compensation. Encapsulation of components in a material such as epoxy resin is under investigation. As an alternative, the sealed case, or "hard shell," is not always applicable. Its disadvantages are the size and weight required to withstand the pressure of the deep ocean environment, means to achieve adequate heat transfer, and the problem of penetrations that can withstand high-pressure differentials. A fluid-filled, pressure-compensated case for these components external to the pressure hull has been the preferred protective approach. This is the alternative that requires consideration of suitable protective fluids.

## CHAPTER I

### FLUID AND LUBRICANT PROPERTIES AND USE CLASSIFICATION

The exploration of the ocean depths has created requirements for fluids and lubricants for which no precedent exists. The hostile environment of the ocean, and not necessarily the sophistication of the equipment, has placed new demands on fluids and lubricants. Fluids will have to withstand exposure to ambient temperatures ranging from 28° to 130° F, pressures up to 20,000 psi, and a chemically corrosive environment.\* Undersea exploration is being performed by means of manned and unmanned submersibles, with externally placed pressure-compensated machinery, manned submerged habitats, and submerged instrument packages, each of which may have fluid or lubricant needs.

Generally speaking, there are three main uses for fluids and lubricants in deep ocean applications:

- Power transmission; i.e., the fluid for a hydraulic system.
- Lubrication; i.e., friction and wear reduction for system bearings and gears.
- Shielding from environment; i.e., a fluid to fill externally placed electric motors, switches, and relay boxes, to protect the components from seawater.

Ideally one fluid could serve all three purposes, but most fluids will not be suitable for all three.

Furthermore, it must be remembered that when products purchased under a military or federal specification are used, properties not specifically required by the specification may vary widely from one manufacturer to another and from one manufacturer's batch to another.

#### Viscosity

Viscosity is one of the most important single properties of any fluid that is to be used for power transmission or for lubrication. In surface vessels, submarines, and aircraft, viscosity

---

\*Abbreviations used in this text are from the GPO Style Manual, 1967, unless otherwise noted.

is no longer a serious problem, since representatives of the various types of hydraulic fluids and lubricants are available in suitable viscosities, and with improved additives to yield very favorable viscosity/temperature relationships. While the effect of temperature is still the major consideration, a new variable, introduced with deep submergence, the viscosity/pressure relationship, is superimposed on the temperature effect.

In nearly all planned uses, as many components as possible are placed external to the pressure hull where the fluid serves as a protective medium for the mechanical and electrical system components and, of course, is subjected to the ambient pressure at the dive depth. Moreover, the fluid in a hydraulic system is usually pressurized to 3000 psi above the ambient pressure to operate the system components. Such systems could subject the fluid to a total of 20,000 psi at the maximum known depth of the ocean.

It is well known that viscosity increases with pressure. The viscosity of pure petroleum oils may increase as much as 30 times at a pressure of 20,000 psi. The viscosity of petroleum oils with polymeric additives that improve the viscosity index exhibits an increase of only 10-15 times the atmospheric pressure value. Silicone oil of low viscosity increases 8-10 times in the same range. Several mathematical relationships for predicting the increase of viscosity with pressure have been studied. The best representation has been obtained from a third-order polynomial expansion of the logarithm of viscosity at pressure which agrees with measured values to within 1%; i.e.,

$$\ln \nu = \ln \nu_0 + bp + cp^2 + dp^3$$

where

$\nu$  = viscosity at the measured pressure

$\nu_0$  = viscosity at atmospheric pressure

$p$  = pressure

$b$  = coefficient characteristic of the fluid measured

$c$  = coefficient characteristic of the fluid measured

$d$  = coefficient characteristic of the fluid measured.

(A straight-line fit logarithm of viscosity versus pressure data,  $\ln \nu = \ln \nu_0 + bp$ , will predict values to within 10% of the measured values. The coefficients of the equations are characteristic of the fluid measured.)

The pressure/viscosity relationship imposes a new restriction on the choice of fluids. The information available at the present time offers some guidelines upon which to base a selection:

- Lower viscosity fluids are less affected by pressure than higher viscosity fluids.
- Low viscosity permits higher speeds in electric motors.
- The viscosities of gas-saturated fluids are less affected by pressure than are those of the gas-free fluids.
- Additives which improve the viscosity/temperature relationship appear to significantly reduce the viscosity change due to pressure increase.
- Low viscosity has also been shown to be a desirable characteristic of fluids used in the satisfactory operation of switching electrical devices in fluids under high pressure. The failure of electrical devices due to the buildup of solid products or "clinkers" between contact surfaces in pressure compensating fluids takes place less readily, the lower the viscosity of the fluid.

The addition of polymeric viscosity index improvers offer an attractive possibility for alleviation of both temperature and pressure effects on viscosity. These materials render a fluid non-Newtonian; that is, its viscosity becomes dependent upon the shear-rate condition to which the fluid is subjected. The system designer must take into account that the apparent viscosity of a non-Newtonian fluid in a system with a high shear rate will be significantly lower than the viscosity measured by conventional laboratory viscometers. The same shear which lowers the viscosity of the fluid, due to its non-Newtonian behavior, has the undesirable property of eventually degrading the viscosity-improving additive (a polymer of high molecular weight) by reducing its molecular weight, thus permanently reducing the viscosity of the fluid.

Viscosity may be an important consideration for fluids which are intended to provide environmental protection for nonmoving electrical and electronic components. There are indications that in the event of sea-water contamination, all other things being equal, fluids of higher viscosity have a greater tendency to keep water in suspension, a characteristic which lowers the dielectric breakdown voltage and insulation resistance of the fluid to unacceptable levels.

Low viscosity may also be desirable in relation to electrical equipment, from the standpoint of heat transfer. The lower the viscosity of the fluid, the more rapid will be the desired dissipation of heat generated by motors, switches, solid-state devices, and other electrical components.

#### Lubricating Ability

The lubricating ability of a fluid or lubricant is a critical consideration in the selection of an immersion medium for moving parts. While viscosity has been separately discussed as a critical property, it also affects lubricating ability. The present requirement for lubrication of moving parts under deep submergence pressure, when considered in the light of the properties of known lubricants, dictates the use of low viscosity fluids. On the other hand, such fluids present serious lubrication problems at atmospheric pressure. A fluid for deep ocean use will have its highest viscosity at the maximum operating depth and thus at the lowest ambient temperature. It will also have its lowest viscosity while operating on the surface or at its shallowest operating depth, where the ambient pressure is at a minimum and ambient temperature is at the maximum. Thus, a fluid may have adequate viscosity for lubrication over most of a machine's operating depth; yet when the machine is operated on the surface, its viscosity may be below acceptable levels for good lubrication. Conversely, a machine may have good efficiency due to low viscosity when operating near the surface and have poor efficiency due to high viscosity when operating at maximum depth. In applications where viscosity is an important factor (motors, gears, and hydraulic systems) it is necessary to consider these operating extremes. A fluid whose viscosity shows a small variation with pressure and temperature and has good lubricating properties would be desirable for that machine. However, in most instances, today, a tradeoff must be made since fluids with these ideal properties do not exist for all required applications.

A similar set of requirements was encountered in "Aerospace" applications where low viscosity lubricants had to be employed due to the extremely low temperature of the operating environment. The solution to the problem was to develop additives to improve the load-carrying ability (i.e., the ability of a lubricant to maintain a film between two moving metal components preventing metal-to-metal contact, despite extremely high pressures), to develop additives to improve the viscosity/temperature relation, and to develop additives to keep the lubricants from oxidizing from the heat generated by less-than-satisfactory lubrication. In addition to the development of lubricants, changes were made in design of the equipment to make it tolerate the low viscosity lubricants. Furthermore, the nature of the application made the relatively short running time and short equipment life acceptable.

"Aerospace"-type lubricants are currently in use in both Navy and commercial deep submergence vehicles. While they have proved satisfactory for present short-term operations, improvements are required for reliable long-term operation in the pressure range expected in the deep ocean environment.

#### Effects of Contamination

It is well known that water in a lubricant reduces the life of loaded rolling angular-contact bearings by accelerating rolling-contact fatigue failure. Water in a lubricant also alters its rheological properties which ultimately affect its lubricating ability for gears and sliding contacts.

Solid contaminants in the lubricant act as abrasives to increase the wear on moving parts, and if solid particles are present in sufficient quantities, the filters and valves in moving systems may become clogged and fail to operate as designed.

The acceptable limits of both sea-water and solid contamination have not been established.

#### Corrosion Protection

Fluids and lubricants for deep ocean uses must provide protection from the corrosive character of the environment, seawater. The fluid or lubricant must be capable of protecting the system from corrosion, for seawater has a high probability of entering the system.

Rust-inhibiting fluids and lubricants of many types have been available for years and are available in the low viscosity types required for deep ocean applications. However, the ability of many fluids to inhibit corrosion has, in the past, been evaluated chiefly in terms of the rust prevention of ferrous metals. To depend on such fluids may be hazardous since there are also nonferrous metals in all deep submergence systems. It is not always possible to use the fluid which has given maximum protection to a mild steel specimen in a laboratory test, since there are numerous examples of rust-inhibited fluids which severely attack nonferrous metals. The specifications of fluids for corrosion inhibition should be prepared, or revised, so that uniform protection is provided for all the metals encountered in the various systems.

A fluid which is to be used for any of the three main functions - power transmission, lubrication, environmental protection - must display the ability to protect all system metals from corrosion. This is a property which must be continually improved so that system components are protected from all forms of corrosion, that is, stress, galvanic, crevice, and pitting, as well as general chemical attack by the action of seawater.

#### Dielectric Properties

A pressure-compensating fluid for electric motors, relays, switching devices, and electronic equipment must have good dielectric properties and ideally should be otherwise inert to the effects of electrical equipment operation.

The dielectric quality of a fluid is measured in terms of electrical resistivity, dissipation factor, and dielectric breakdown voltage. Dielectric properties of a fluid as received result from its chemical nature and from the presence of additives in certain cases. In practice, several factors affect dielectric properties during usage.

Contamination of the fluid by sea-water leakage is an important cause of failure. As little as 0.1% contamination by seawater reduces the resistivity of some fluids below suggested limits. Fluid chemical changes and carbon produced by arc discharge through the fluid or from brush wear also lower its resistivity and breakdown voltage below suggested limits. Equipment failures due to lowered resistivity and dielectric breakdown voltage also have been caused by contamination with metallic

particles resulting from the wear processes of moving parts. A commonly observed failure at high pressures and high current densities of fluid-compensated electrical switching devices is the deposition of carbon or silica on electrical contacts, where arcing occurs. At present no fluid has been found that can provide long life under these conditions.

#### Dissipation Factor

The need for fluids and lubricants with corrosion protection properties and improved lubricating ability has led to the formulation of products which contain polar additives and those in which water is soluble or with which water is miscible. In addition to lowering the resistivity and dielectric breakdown voltage, the polar materials also decrease the efficiency of an electric motor by transformation of electrical energy into heat energy in a nonsinusoidal alternating-current system. A useful measure of this property is the dissipation factor of the fluid. A high dissipation factor predicts dielectric heating losses. Dissipation factor is defined as the tangent of the loss angle expressed as percent for a dielectric material. (A perfect insulator would have a loss angle of 0 degree and thus a dissipation factor of 0%.) Dielectric heating losses are proportional to the square of the voltage gradient, frequency of applied voltage, dielectric constant, and dissipation factor. The trend in submersible equipment is to use inverters and choppers, without filters to save weight; thus, high frequencies are encountered. It then becomes obvious that dielectric losses through the fluid will increase if the dissipation factor of the immersion fluid is high or if it increases due to contamination. The losses would not be immediately obvious in laboratory bench studies where commercial electric power is the energy source. In actual naval service unfiltered inverters and choppers with a large percentage of high-frequency component are used. Evaluation methods which consider this operating condition have not been devised.

#### Ability to Form Stable Emulsions

When the fluid encapsulating any electrical equipment becomes sea-water contaminated, it is clear from the statements in the preceding paragraphs on dielectric properties that efficiency may be lost or failure may occur. The quantity of the seawater in the fluid and its state of subdivision may determine whether failure or efficiency losses will occur. This factor is especially important in the operation of electric motors where motor shaft seals may allow leakage of the external seawater. If the oil

permits the water to separate in large drops, a short circuit and catastrophic failure can occur when one of the drops of seawater bridges the electrical gap. If, on the other hand, the water is emulsified in extremely small droplets, the motor may still operate, even though dielectric heating and loss of efficiency may occur. In this case, even though emulsified water in the immersion fluid may ultimately lead to motor failure, the failure is not of the catastrophic type. Present methods of evaluation of emulsifying ability have not yet been correlated with performance capability. The limits of emulsified water in oil and the limits of polar-type emulsifiers have not been established, nor has the use of nonpolar emulsifiers been investigated. These considerations are not so important in electrical components other than motors where little agitation occurs.

#### Material Compatibility

The use of compatible materials in a system which is to be fluid-filled is of prime importance regardless of the fluid used. No system should be designed without considering the compatibility of the fluid and material. When a fluid is selected, a list of compatible materials should be compiled or consulted to determine whether the metals, coatings, insulations, seals, and elastomers in the system are compatible. If a specific material is required for a particular application, then the fluid selection must be governed by its compatibility with that material. Incompatible coatings or elastomers may cause the formation of sludge in the fluids. System leaks can develop when incompatible elastomers are used for sealing. Electrical failures can result from the use of incompatible fluids and insulating materials. Accelerated corrosion usually results when a fluid is in contact with an incompatible metal.

#### Volatility and Toxicity

These two related properties require consideration for any fluid or lubricant application. Nearly all volatile materials pose a certain degree of toxicity, but not all toxic liquid materials are volatile. The toxicity may be exhibited in various ways. Volatile materials may affect lungs, bronchi, and nasal passages either by irritant action, by chemical or solvent action on tissue, or by forming an inert coating to interfere with the respiratory process. Toxic liquids in contact with the skin or eyes cause irritation, destruction of tissue by chemical action, or dermatitis, in sensitive individuals. Inert liquids such as silicone oils, which are not considered toxic in the

usual sense of the word, present special problems when they get in the eyes or are inhaled. Their insolubility and immiscibility with water make it impossible for body fluids to carry them away, and in the case of the eye, a condition similar to cataract can result. In most cases, fluids and lubricants used in deep submergence will be volatile and toxic. Such use, however, will be in capsules external to the pressure hull of manned vehicles. The breathing atmospheres of manned habitats will have to be reviewed, particularly from the standpoint of sources of fluid vapors or solid lubricant dust. The volatility of all solid and liquid lubricants should be specified properly for all deep ocean applications. The effect of pressure should be included since in most cases volatility increases with pressure.

#### Compressibility and Density

Ideally a liquid is incompressible, but existing fluids and lubricants show 5%-7% decrease in volume in the case of petroleum fluids, and 8%-13% in the case of silicone-base fluids when they are in the pressure range from atmospheric to 20,000 psi. Fluid-encapsulated systems must be designed to allow sufficient fluid to ensure that the system components will be lubricated and protected from the environment in spite of any volume reduction in the fluid. Compressible liquids can cause some operational sluggishness if they are employed in a hydraulic system.

It is desirable to have liquids with a density less than 1.0 gram per cc at atmospheric pressure since this will save weight in the system. All of the petroleum oils and most of the applicable silicone oils have a density of less than 1.0 at atmospheric pressure. The more inert classes of liquids all have high densities and are not being generally utilized for that reason. Since there is an increase in density with an increase in pressure and the weight of the fluid head will change, the circulation rate may decrease for fluids or lubricants which are pump-circulated. The density as well as the compressibility of fluids as a function of both temperature and pressure should be considered by vehicle and machinery designers.

#### Chemical Stability

The term "chemical stability" is used here to indicate the ability of a fluid or lubricant to resist oxidative, hydrolytic, or thermal degradation. Failure of a fluid or lubricant to resist oxidation or hydrolysis creates a hostile environment for the system components even in the absence of contamination. Such

breakdown results in the formation of sludge and fluid viscosity changes which can promote wear and impair system operation. In the case of oxidation or hydrolysis, organic acids are formed which can be corrosive to system metals. Such breakdown of fluids and lubricants is considered normal and likely to occur in any type of service to various degrees. The problem of arcs caused by the make and break of electrical contacts has already been discussed under dielectric properties. Under high pressure and high current densities an electric arc will cause the formation of large particles of carbon and silica. In some cases these particles bridge the gap between electrical contacts preventing complete interruption of the circuit.

All fluids (hydrocarbons and silicones) tested thus far under electrical arcing also produce gaseous decomposition products. The accumulation of gaseous products in a pressure compensator, under submerged conditions, presents the problem of possible rupture of compensating chamber walls, or flexible membranes, on surfacing. Since sizable quantities of gas have been observed under experimental conditions, a means of safely bleeding off gases while surfacing will be required.

Accurate figures on the rate of gas production under various arcing conditions are not available.

Oxidation resistance, arc-breakdown resistance, and thermal-breakdown resistance tests and standards have not been developed to provide selection criteria for fluids and lubricants.

#### Fire Resistance

Fire hazards exist in hydraulic systems, air compressor systems, and fluid-lubricated systems which are located inside the pressure hull of a submersible; in such cases care must be taken to eliminate air from the system and prevent overheating to reduce the fire hazard. Care must always be taken to prevent fire while draining or filling any system using a combustible fluid. The low viscosity fluids for deep submersibles are more readily ignited than the fluids used on surface ships and conventional submarines; greater precautions must be taken to prevent ignition. Petroleum oils and silicone oils are both relatively easily ignited. Fluids with flash points below 300° F should be treated with extreme care. Suitable published precautions should be observed. The more fire-resistant fluids and lubricants are among the inert fluids having densities which are too high for consideration.

## Cost and Availability

The small volume and specialized nature of the deep ocean systems have caused the designers to consider the cost factor of fluids as secondary. Fluid availability has been the principal consideration. The petroleum-based fluids are usually readily available and procurable in drum quantities at a reasonable cost. The specially purified aerospace oils are moderately expensive. If and when fluid cost becomes a problem, the use of the relatively expensive silicone fluids will have to be limited to critical application. Specially developed new fluids will be expensive due to high development and testing costs and because the limited market for deep ocean applications at the present time will not encourage large volume production and competition which tend to reduce costs.

-----

This chapter has attempted to define and discuss the factors involved in the use of fluids and lubricants in deep ocean applications. At the time of writing, the above selection and definitions of the critical properties are those which appear to be the main factors to consider in the selection of a fluid or lubricant for use in a deep ocean application. It is the intent to revise this handbook on an annual basis. When it is established that a new consideration is needed, it will be added. As items prove to be noncritical they will be deleted.

CHAPTER II  
METHODS FOR ESTABLISHING FLUID PROPERTIES

The methods described in this chapter have all been developed especially for the conditions of deep ocean applications, and sea-water and solid contamination anticipated for fluids and lubricants in deep ocean equipment. These methods are in various states of development, and as yet limits have not been established for all methods. Ratings in some cases are still on a comparative basis. Standard methods, such as those described by the American Society for Testing and Materials (ASTM), Federal Test Method Standard No. 791a, and the Society of Automotive Engineers (SAE) Aerospace Recommended Practices (ARP), are not described in this chapter. Procedures described in detail by other reports will be referenced when data are presented in Chapter III. The methods described in this chapter are tentative and may have published counterparts which would be preferable. The results of these methods will be compared with the published methods in the future if any are found to exist. All methods and data will be reviewed periodically and replaced or updated in subsequent revisions.

## CORROSION AND COMPATIBILITY PROCEDURES

### Cl. Ambient Pressure Stirred Corrosion Procedure

Scope - This method conducted at atmospheric pressure is intended to measure the relative protection provided by fluids and lubricants to metals and alloys used in deep submergence components when exposed to contamination by seawater.

Outline of Method - A sample of oil in a glass beaker is brought to a predetermined temperature in an oil bath. Corrosion specimens isolated from each other are mounted on a metal rod which is then stirred in test oil. Seawater is added to the test oil. After the desired exposure period, the specimens are cleaned, dried, weighed, and photographed to measure degree of corrosion.

#### Apparatus

a. The heating bath, stirring motor and assembly, beaker and beaker cover are the same as those used in ASTM (Method) D-665.

b. A 304 stainless steel rod, 9 1/2 inches long and 1/4 inch in diameter, with 4 1/2 inches of 1/4-inch 20 threads in one end is substituted for the ASTM D-665 stirrer. Stainless steel nuts (304) (1/4-inch 20) are used to hold specimens on the rod.

c. Spacers for specimens shall be made of polytetrafluoroethylene (PTFE). They shall be cut from 1/4-inch inside diameter (ID), 3/8-inch outside diameter (OD) tubing and shall be 1/8 inch thick.

d. Corrosion specimens shall be 1 x 1 x 0.032 inch with a 1/4-inch hole in the center. The specimens shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The specimen shall be of any alloy or metal used in the deep submergence components. Those used by NAVSHIPRANLAB, Annapolis are shown in Figure 1. A typical specimen rod assembly is shown in Figure 2.

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

STEEL, Stainless, Type 316

ALUMINUM 6061, Specification QQ-A-250-11

COPPER-NICKEL, 70-30, Specifications  
MIL-C-15726 or MIL-T-00/6420

STEEL, QQ-S-698, Grade 1009

ALUMINUM, QQ-A-250-4b

COPPER, QQ-C-576a

NICKEL-COPPER, QQ-N-281, Class A, Monel 400

BRONZE, MIL-B-16541A(WEP) (1/16 inch thick)

PHOSPHOR-BRONZE, QQ-R-750, Composition A

SILVER BASE BRAZING ALLOY, MIL-B-15395A,  
Grade IV

STEEL, Galvanized, Electrodeposited,  
QQ-Z-325A, Type II, Class I

Specification for Items Above

Metal Specimens, 1 x 1 x 0.032 inch with a  
1/4-inch hole in center, finish to conform  
to that given in Federal Test Method  
Standard No. 791a, Method 5308.4

Figure 1 (C1)  
Specimens Used

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

1 - Copper	7 - Steel, 100%
2 - 316 Stainless Steel	8 - Aluminum, QQ-A-250-11
3 - Copper-Nickel, 70-30	9 - Bronze
4 - Aluminum, QQ-A-250-4b	10 - Monel
5 - Phosphor, Bronze	11 - Silver Base Braze Alloy
6 - Galvanized Steel	

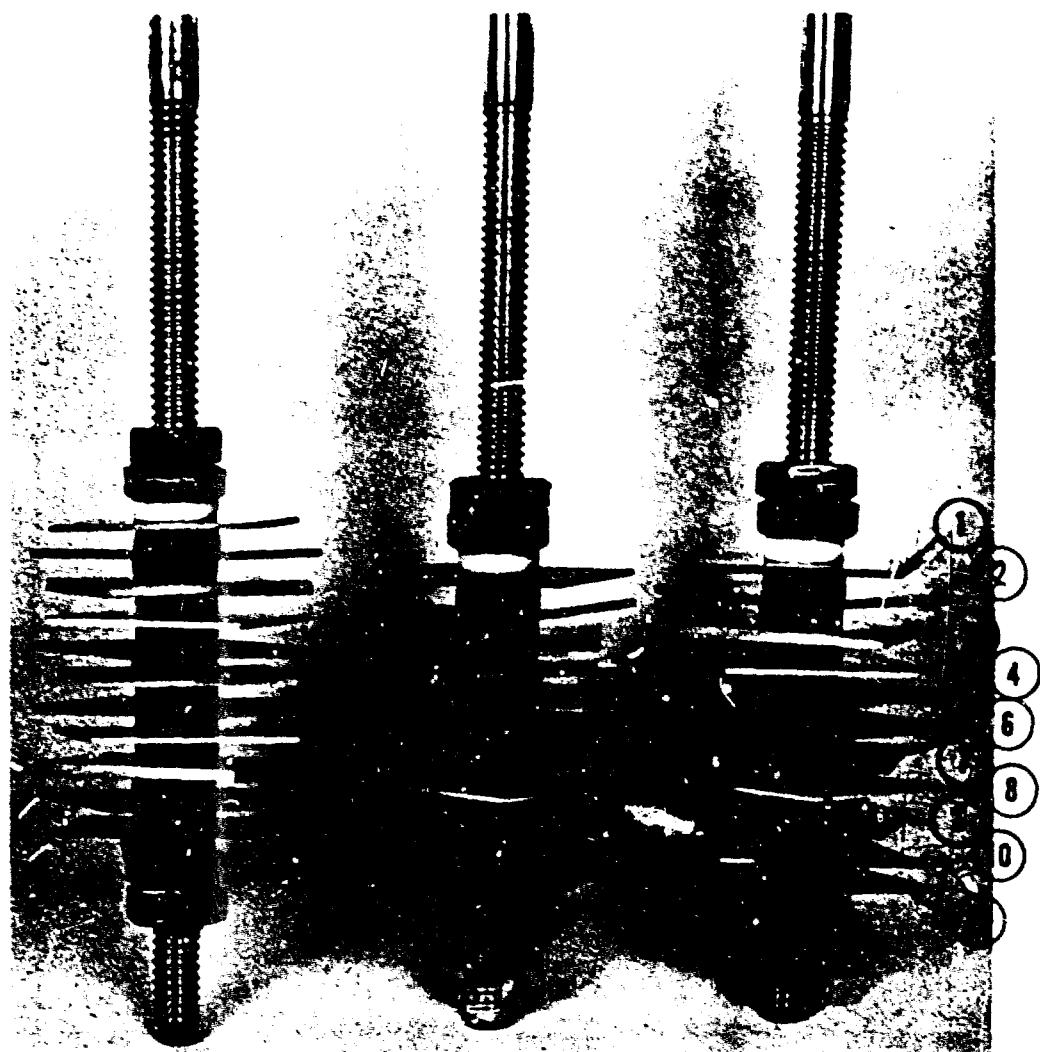


Figure 2 (C1)  
Typical Specimen Rod Assembly

### Materials

- a. Naphtha solvent conforming to ASTM-D-91 method.
- b. Freon TF solvent-trichlorotrifluoroethane obtained from E. I. du Pont de Nemours and Company.
- c. Aluminum oxide polishing compound, 150 grit.
- d. Seawater, ASTM D-665.
- e. PTFE tape, 1/2-inch wide, Scotch Brand No. 48 obtained from Minnesota Mining and Manufacturing Company.
- f. Typewriter brush, Federal Specification H-B-00681C.

### Preparation of Corrosion Specimens

- a. Handle specimens with disposable polyethylene gloves.
- b. Flush with naphtha to remove preservatives.
- c. Polish with 150 grit aluminum oxide powder on medicinal cotton wads (do not polish plated specimens).
- d. Make polish strokes in one direction.
- e. Turn specimen 90° and polish until previous polish marks are removed.
- f. Brush with camel hair brush.
- g. Use wash bottle to flush specimens with jet of naphtha then with Freon TF.
- h. Air dry and place in desiccator.
- i. Weigh on semimicrobalance; record weight to 0.00001 gram.

### Procedure

- a. Place 270-ml test oil in a clean beaker. Heat in an oil bath to 140° F.
- b. Clean the specimen rod with soap and water, then with distilled water and oven dry at 220° F.

- c. Wrap the rod with PTFE tape to insulate from specimens.
- d. Assemble specimens as shown in Figures 1 and 2. Use clean polyethylene gloves to handle specimens and rod. Separate specimens from each other and end nuts using the PTFE spacers. Secure with nuts on both ends.
- e. Insert the rod assembly in stirring device with specimens in oil and beaker cover in place.
- f. Stir for 1 hour.
- g. Add 30-ml ASTM D-665 seawater while stirring. Plug excess holes in the cover with inert material, such as glass plugs.
- h. Inspect the fluid level daily and add distilled water to make up for losses by evaporation.
- i. At the end of the test period remove specimens and store in naphtha prior to cleaning.
- j. Clean the specimens by successive flushes with naphtha and brushing with a naphtha-wet typewriter brush.
- k. Make a final flush with Freon TF; then place the specimens in a desiccator to condition prior to weighing.
- l. Record weight changes and changes in appearance of specimens by written descriptions and photographs.

## C2. 20,000 PSIG Pressure-Cycled Compatibility Procedure

Scope - This method is intended to measure the effects of cycled-pressure on deep submergence fluid compatibility with materials of construction.

Outline of Method - A high-pressure reaction vessel, filled with a temperature- and pressure-transfer oil, is brought to a test temperature of 140° F. A test cell consisting of metallic or nonmetallic compatibility specimens immersed in the oil being studied contained in a PTFE bag is immersed in the transfer oil. The reaction vessel is closed. The maximum selected test pressure is applied to test assembly via the transfer oil and then returned to ambient pressure over a 30-minute cycle. The test temperature and pressure cycling are maintained throughout the test period (usually 30 days). At the end of the test, specimens and fluid are examined for evidence of physical and chemical changes and performance properties.

### Apparatus

a. Reaction vessel - The reaction vessel shall have 4-inch ID and 16-inch useful height. It shall have a 3300-ml capacity. The top shall have fluid inlet and outlet ports and a thermo-couple well.

b. Test cell - The fluid specimens are contained in a PTFE cylindrical bag (3-inch ID, 8-inch-long) with 304 stainless steel end closures. (See Figure 1.)

c. Specimen holder - The specimen holder shall be of any design suitable to hold specimens in fluid with ample space between specimens and between test cell wall and specimens. It shall be of 304 stainless steel. A typical holder for metal specimens is shown in Figure 2.

d. Spacers - The spacers shall be made of either 304 stainless steel or PTFE. They shall be cut from 1/4-inch ID, 3/8-inch OD tubing and shall be 1/8 inch thick.

e. Constant-temperature bath - The constant-temperature bath shall contain MS 2190-TEP petroleum oil as the heating medium. It shall be designed to permit immersion of the reaction vessel up to the lower rim of the locking nut. The bath shall be capable of maintaining the vessel and transfer oil at any temperature between 100° and 250°±2° F. During pressure cycles, the test oil temperature varies, for example, at the selected pressure, transfer oil temperature will vary from the set temperature of 140° F. as the pressure is released and applied, from 125° to 155° F.

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

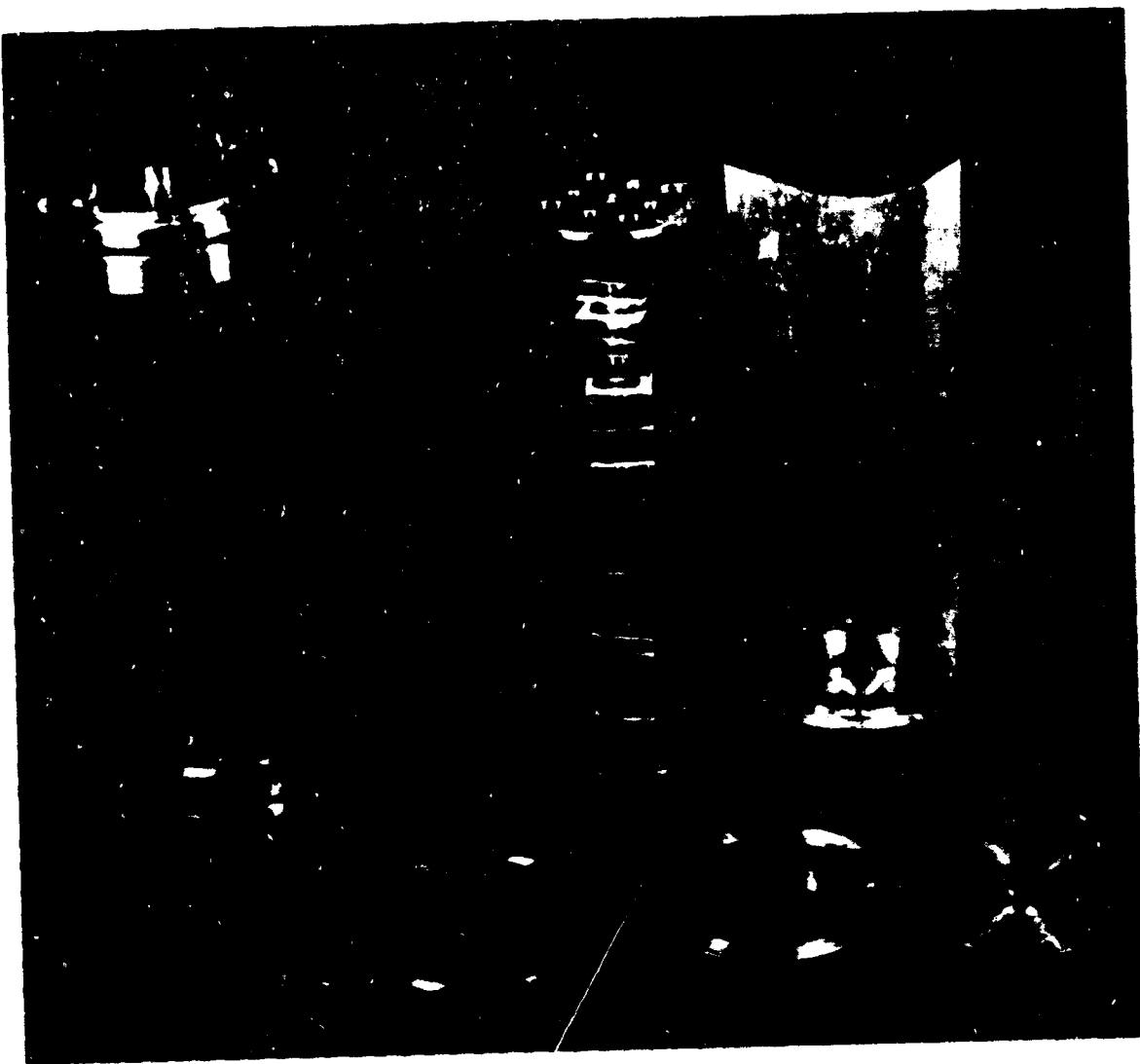


Figure 1 (C2)  
Test Cell

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY



Figure 2 (C2)  
Typical Metal Specimen Holder

f. Pressure supply - The pressure shall be supplied by a high-pressure pump, such as a 30,000 psig Sprague diaphragm pump, Model S-216-CPR-300. All tubing and fittings shall be high-pressure 304 or 316 stainless steel. The pump controls shall be capable of linearly cycling the pressure in the reaction vessel from 0-20,000 psig and back to 0 psi over a 30-minute period, with a variation of  $\pm 200$  psig. A schematic diagram of the pressure supply is shown in Figure 3.

g. Recording potentiometer - A recording potentiometer capable of recording oil temperatures from  $100^\circ$  to  $250^\circ \pm 2^\circ$  F shall be used.

h. Specimens

(1) Metal specimens shall be of any deep submergence alloy or metal to be studied. The size shall be 1 x 1 x 0.032 inch with a 1/4-inch hole in the center. The specimens shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The metals used by NAVSHIPRANLAB Annapolis are given in Figure 4.

(2) Nonmetallic specimens shall be of any deep submergence elastomer, plastic, or insulating material contacting fluids of interest. Where possible, specimens shall be prepared in a Type C dumbbell shape as in ASTM D-412-66.

Materials

- a. Naphtha solvent, conforming to ASTM D-91 method.
- b. Freon TF solvent, trichlorotrifluoroethane, E. I. du Pont de Nemours and Company.
- c. Aluminum oxide polishing compound, 150 grit.
- d. Seawater, ASTM D-665.
- e. PTFE tape, 1/2-inch-wide, Scotch Brand No. 48, Minnesota Mining and Manufacturing Company.
- f. Typewriter brush, Federal Specification H-B-00681C.
- g. Temperature and pressure transfer oil - MIL-L-17331, MS 2190-TEP.

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

A - Air Driven Pump (rated 30,000 psig)	H' - Check-Valve (10 psig working pressure)
B - Pump reservoir (capacity 3 gallons)	I - Solenoid Valve (110 vac)
C - Rupture Assembly (set 22,500 psig)	J - Bleed-Down Sump (1 quart)
D - Pressure gage (25,000 psig)	K - Support Stand (30 x 36 x 40 inches)
E - Air Operated, Flow Control Valve (50,000 psig)	L - Heated Oil Bath (20 gallons, 140° F, 2190-TEP)
F - Pneumatic Indicating Controller (100 psig)	M - Reaction Vessel (3300-ml, rated 30,000 psig at 125° F)
G - Microset Hand Valve	N - Thermocouple
H - Check-Valve (40 psig working pressure)	

All high-pressure tubing - 1/4-inch OD, 1/16- or 3/32-inch ID, rated 60,000 psig.

All valves, tees, elbows - rated 30,000 psig (superpressure).

Auxiliary Equipment (Not Shown)

High-Speed Bath Stirrer  
Immersion heaters (1500 watts)  
Bath Temperature Control  
Recording Potentiometer  
Air Operated Cycling Device  
Electric Timer  
Air Filters, Regulators, etc

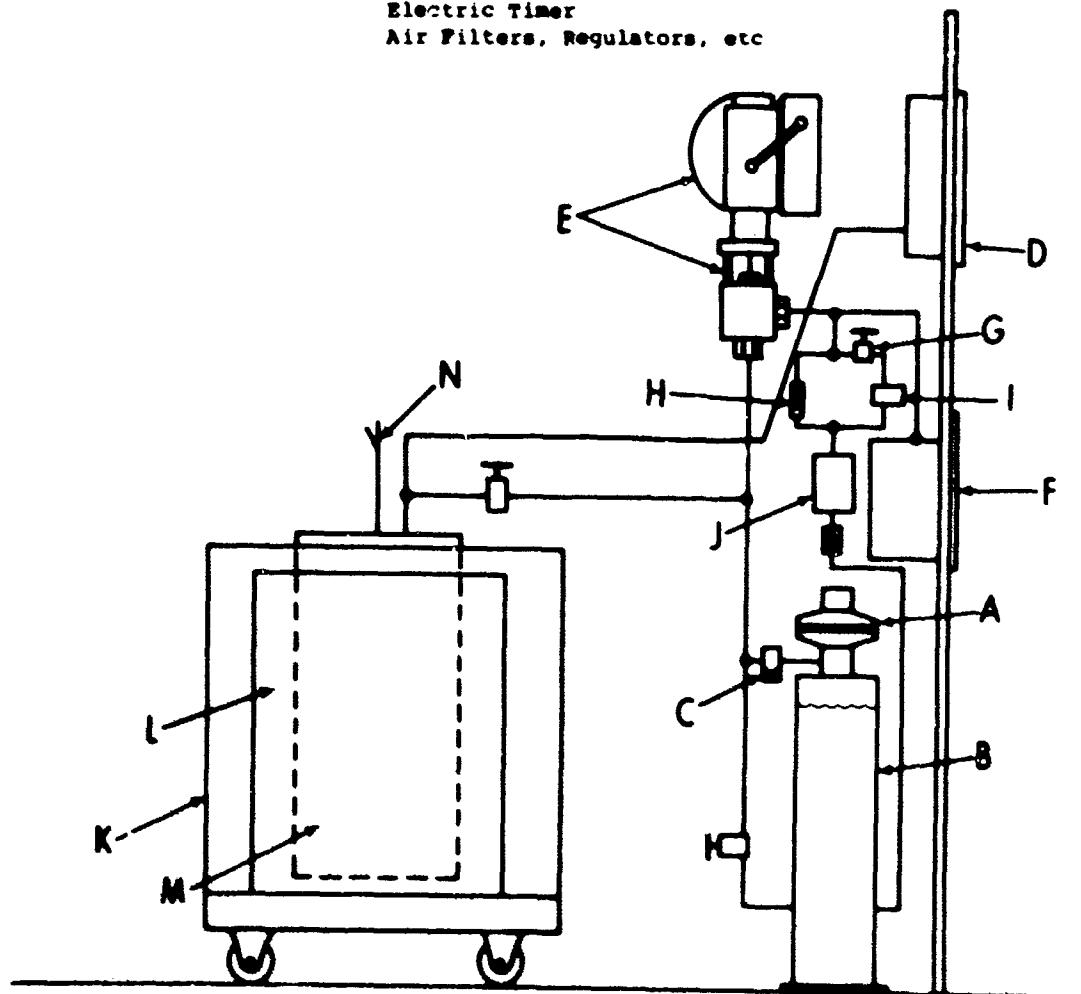


Figure 3 (c2) - Cycling Unit

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

STEEL, Stainless, Type 316

ALUMINUM 6061, Specification QQ-A-250-11

COPPER-NICKEL, 70-30, Specifications  
MIL-C-15726 or MIL-T-00/6420

STEEL, QQ-S-698, Grade 1009

ALUMINUM, QQ-A-250-4b

COPPER, QQ-C-576a

NICKEL-COPPER, QQ-N-281, Class A, Monel 400

BRONZE, MIL-B-16541A(WEP) (1/16 inch thick)

PHOSPHOR-BRONZE, QQ-B-750, Composition A

SILVER BASE BRAZING ALLOY, MIL-B-15395A,  
Grade IV

STEEL, Galvanized, Electrodeposited,  
QQ-Z-325A, Type II, Class I

Specifications for Items Above

Metal Specimens, 1 x 1 x 0.032 inch with a  
1/4-inch hole in center, finish to conform  
to that given in Federal Test Method  
Standard No. 791a, Method 5308.4

Figure 4 (C2)  
Metal Specimens Used

### Preparation of Sample Container and Specimen Holder

a. The PTFE bag, end pieces, and specimen holder shall be successively washed with ASTM D-91 naphtha, soap and water, and distilled water; then oven dried at 140° F.

### Preparation of Specimens

a. Metallic specimens shall be cleaned, polished, and weighed as in the "Ambient Pressure Stirred Corrosion Procedure," Method Cl.

b. Nonmetallic specimens shall be prepared, cleaned, and volume measured as in ASTM D-471-66.

c. The specimens shall be attached to the specimen holder so as to provide space between the individual specimens and also between the specimens and the wall of test cell so that all parts of specimen are flooded by test fluid. Where insulated metallic specimens are used, the order of assembly shall be as given in Method Cl. When metallic couples also are to be studied, the order of assembly shall be as shown in Method C4 ("20,000 ~~HR~~IG Stirred Corrosion Procedure"), except that the insulated specimens shall be placed on the specimen holder above the coupled specimens.

### Procedure

a. Bring reaction vessel and transfer of oil to test temperature.

b. Assembly of test cell.

(1) The PTFE bag is fitted into the bottom and top closures.

(2) The specimen assembly is inserted into the bag through a removable part of top closure placed on the bag.

(3) The cell is filled with 825 ml of test fluid through the top port, taking care to purge out the air. The top port is closed.

(4) Get the total weight of the test cell. The test cell is again weighed after the test period. The weights are obtained to determine whether the test cell leaked during the test.

c. Place the test assembly in the reaction vessel in transfer oil.

d. If sea-water contaminant is to be used, allow the test cell to remain in the reaction vessel for 1 hour. Then remove the test cell from the reaction vessel and add seawater through the top port. Close the top port and return the test cell to the reaction vessel.

e. Close the reaction vessel, placing the thermocouple end at the top of the test cell.

f. Add sufficient additional transfer oil to finish filling the reaction vessel and purging out the air. Close the reaction vessel.

g. Begin pressure cycling and maintain pressure cycling and test temperature for the test period.

h. At the end of the test period remove the test cell.

i. Separate the specimens and the test oil.

j. Measure the properties of the test oil to detect changes (viscosity, acid content, density, metal content, etc).

k. Measure changes in the specimens.

(1) Clean and weigh the metal specimens as in Method C1.

(2) Determine volume, hardness, tensile strength, and elongation changes in the nonmetallic specimens as in ASTM D-471-66.

### C3. 20,000 PSIG Static Compatibility Procedure

Scope - This method is intended to measure the effects of pressure on deep submergence fluid-material compatibility.

Outline of Method - A high-pressure reaction vessel, filled with a temperature-pressure transfer oil, is brought to a test temperature of 140° F. A test cell, consisting of metallic or non-metallic compatibility specimens immersed in the oil being studied contained in a PTFE bag, is immersed in the transfer oil. The reaction vessel is closed, and the test pressure, 20,000 psig maximum, is applied to the contents of the reaction vessel. Temperature and pressure are maintained constant throughout the test period. At the end of the test the specimens and the fluid are examined for evidence of physical and chemical changes and performance properties.

#### Apparatus

a. Reaction vessel - The reaction vessel shall have a 3 1/2-inch ID and a 12-inch useful height. It shall have approximately a 2000-ml capacity. The top shall have fluid inlet and outlet ports and a thermocouple well.

b. Test cell - The fluid and specimens are contained in a PTFE cylindrical bag with 304 stainless steel end closures as shown in Figure 1.

c. Specimen holder - The specimen holder shall be of any design suitable to hold specimens in the fluid with ample space between specimens and between the test cell wall and specimens. It shall be of 304 stainless steel. A typical holder for metal specimens is shown in Figure 2.

d. Spacers - Spacers shall be made of either 304 stainless steel or PTFE. They shall be cut from 1/4-inch ID, 3/8-inch OD tubing and shall be 1/8-inch-thick.

e. Constant-temperature bath - The constant-temperature bath shall contain MS 2190-TEP petroleum oil as heating medium. It shall be designed to permit immersion of the reaction vessel up to the lower rim of the locking nut. The bath shall be capable of maintaining the vessel and transfer oil at any temperature between 100° and 250°±2° F.

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY



Figure 1 (C3)  
Test Cell

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

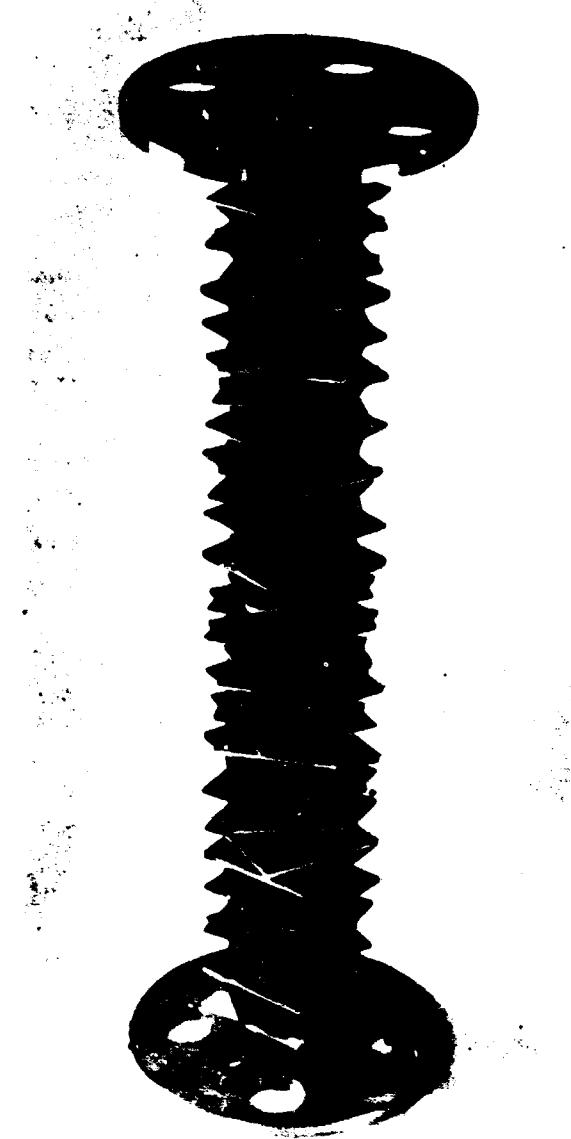


Figure 2 (C3)  
Specimen Holder

f. Pressure supply - The pressure shall be supplied by a high-pressure pump, such as a 30,000 psig Sprague diaphragm pump, Model 8-216-CPR-300. All tubing and fittings shall be high-pressure 304 or 316 stainless steel. The pump shall be capable of maintaining the test oil at  $0-20,000 \pm 25$  psig. A schematic of the system is shown in Figure 3.

g. Recording potentiometer - A recording potentiometer capable of recording oil temperatures from  $100^{\circ}-250^{\circ} \pm 2^{\circ}$  F shall be used.

h. Specimens

(1) Metallic specimens shall be of any deep submergence alloy or metal to be studied. The size shall be  $1 \times 1 \times 0.032$  inch with a 1/4-inch hole in the center. The specimens shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The metals used by NAVSHIPRANLAB, Annapolis are given in Figure 4.

(2) The nonmetallic specimens shall be of any deep submergence elastomer, plastic, or insulating material contacting fluids. Where possible, specimens shall be prepared in a Type C dumbbell shape as in ASTM D-412-56.

Materials

- a. Naphtha solvent, conforming to ASTM D-91.
- b. Freon TF solvent, trichlorotrifluoroethane, E. I. du Pont de Nemours and Company.
- c. Aluminum oxide polishing compound, 150 grit.
- d. Seawater, ASTM D-665.
- e. PTFE tape, 1/2-inch-wide, Scotch Brand No. 48, Minnesota Mining and Manufacturing Company.
- f. Typewriter brush, Federal Specification H-B-00681C.
- g. Temperature and pressure transfer oil MIL-L-17331, MS 2190-TEP.

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

A - Air Driven Pump (rated 30,000 psig)	G - Support Stand (30 x 36 x 40 inches)
B - Pump Reservoir (capacity 3 gallons)	H - Heated Oil Bath (20 gallons, 140° F, 2190-TEP)
C - Pressure Generator (30,000 psig) 11 cc)	I - Reaction Vessel (2000-ml, rated 30,000 psig at 125° F)
D - Pressure Gage (25,000 psig)	J - Thermocouple
E - Rupture Assembly Set (22,000 psig)	
F - Fluid Separator (325 cc, 30,000 psig at 72° F)	

All tubing - 1/4-inch OD, 1/16- or 3/32-inch ID, rated 60,000 psig.  
All valves, tees, elbows - rated 30,000 psig.  
All connections use superpressure fittings.

Auxiliary Equipment (Not Shown)

High-Speed Bath Stirrer  
Immersion Heaters (1500 watts maximum)  
Bath Temperature Control  
Recording Potentiometer  
Air Lines, Filters, Pressure Regulators, etc

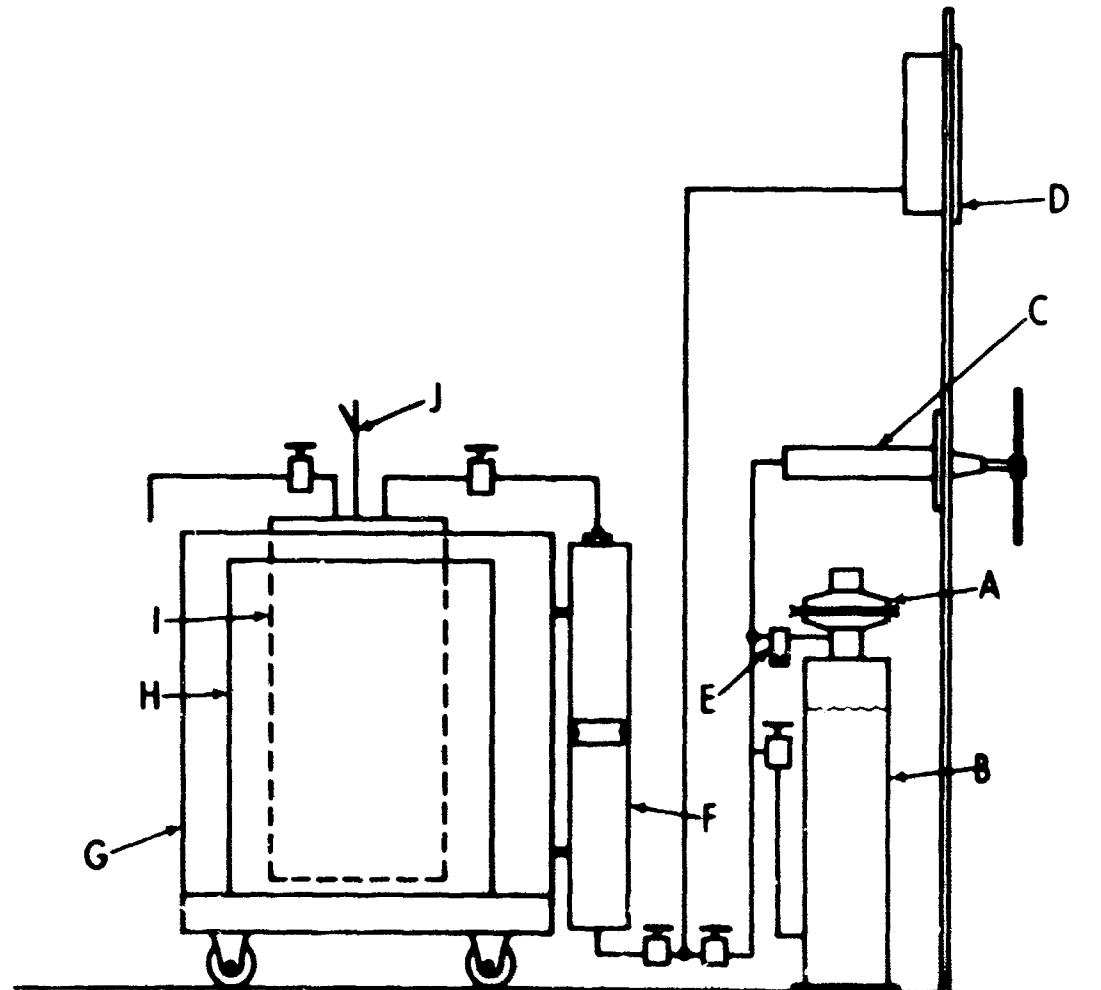


Figure 3 (C3) - 20,000 PSIG Static Test Unit

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

STEEL, Stainless, Type 316

ALUMINUM 6061, Specification QQ-A-250-11

COPPER-NICKEL, 70-30, Specifications  
MIL-C-15726 or MIL-T-00/6420

STEEL, QQ-S-698, Grade 1009

ALUMINUM, QQ-A-250-4b

COPPER, QQ-C-576a

NICKEL-COPPER, QQ-N-281, Class A, Monel 400

BRONZE, MIL-B-16541A(WEP) (1/16 inch thick)

PHOSPHOR-BRONZE, QQ-B-750, Composition A

SILVER BASE BRAZING ALLOY, MIL-B-15395A,  
Grade IV

STEEL, Galvanized, Electrodeposited,  
QQ-Z-325A, Type II, Class I

Specifications for Items Above

Metal Specimens, 1 x 1 x 0.032 inch with a  
1/4-inch hole in center, finish to conform  
to that given in Federal Test Method  
Standard No. 791a, Method 5308.4

Figure 4 (C3)  
Metal Specimens Used

### Preparation of Sample Container and Specimen Holder

a. The PTFE bag, end pieces, and specimen holder shall be washed with ASTM D-91 naphtha, soap and water, distilled water, and oven-dried at 140° F.

### Preparation of Specimens

a. Metallic specimens shall be cleaned, polished, and weighed as in "Ambient Pressure Stirred Corrosion Procedure," Method C1.

b. Nonmetallic specimens shall be prepared, cleaned, and volume measured as in ASTM Method D-471-66.

c. The specimens shall be attached to the specimen holder so as to provide space between specimens, and between the specimens and the wall of the test cell so that all parts of the specimen are flooded with the fluid. Where insulated metallic specimens are used, the order of assembly shall be as given in Method C1. When metallic couples also are to be studied the order of assembly shall be as shown in the "20,000 Stirred Corrosion Procedure," Method C4, except that the insulated specimens shall be placed on the specimen holder above the coupled specimens.

### Procedure

a. Bring reaction vessel and transfer oil to test temperature.

b. Assembly of test cell.

(1) Fit PTFE bag into the bottom and top closures.

(2) Insert the specimen assembly into the bag through removable part of the top closure placed on the bag.

(3) Fill the cell with 825 ml of test fluid through the top port, taking care to purge out the air. Close the top port.

(4) Determine the total weight of the test cell. This is done to determine if the cell leaks during test. The test cell weight is again measured after the test period.

c. Place the test assembly in the reaction vessel in transfer oil.

d. If sea-water contaminant is to be used, allow the test cell to remain in the reaction vessel for 1 hour. Then remove the test cell from the reaction vessel and add seawater through the top port. Close the top port and return the test cell to the reaction vessel.

e. Close the reaction vessel, placing the thermocouple end at the top of the test cell.

f. Add sufficient additional transfer oil to fill the reaction vessel and purge out the air and close the vessel.

g. Bring the system to test pressure. Maintain constant pressure and temperature throughout the test.

h. At the end of the test period remove the test cell from the reaction vessel and separate the specimens and the test fluid.

i. Measure the properties of the test fluid to detect changes (viscosity, acid content, density, metal content, etc).

j. Measure changes in the specimens.

(1) Clean, weigh, and photograph the specimens as in Method C2 ("20,000 PSIG Pressure-Cycled Compatibility Procedure").

(2) Determine the volume, hardness, tensile strength, and elongation changes in the nonmetallic specimens as in ASTM D-471-66.

#### C4. 20,000 PSIG, Stirred Corrosion Procedure

Scope - This method is intended to measure the relative protection provided to metals and alloys used in deep submergence equipment upon contamination with seawater at high ambient pressures.

Outline of Method - A sample of test oil is brought to a pre-determined temperature in a high-pressure reaction vessel. A weighed metal specimen assembly is immersed in the oil, and the stirrer blade and vessel cover are fitted onto the vessel. After stirring for a 1-hour conditioning period, the desired amount of sea-water contaminant is added to the oil. The desired test pressure is applied to the vessel contents. The test temperature, pressure, and stirring are maintained for a predetermined reaction period (usually 30 days). The specimen assembly is removed from the vessel. The specimens are cleaned, weighed, and photographed.

#### Apparatus

a. Reaction vessel - The reaction vessel shall have a 3 5/8-inch ID and a 13-inch useful height. It shall have a 2100-ml capacity and be made of, or completely lined with, a corrosion resistant alloy, such as Hastelloy C. The stirrer shall have a speed of 1000±50 rpm. The vessel cover shall have fluid inlet and outlet ports, thermocouple well, and blowout disk assembly.

b. Specimen holder - The specimen holder shall be of 304 stainless steel and of a configuration so that up to 50 specimens are held between stirrer and wall. Figure 1 shows a typical holder and specimen array.

c. Constant-temperature bath - The constant-temperature bath shall contain MS 2190-TEP petroleum oil as a heating medium. It shall be designed to permit the immersion of the reaction vessel up to the lower rim of the locking nut. The bath shall be capable of maintaining the test oil at any temperature between 100°-250°±2° F.

d. Pressure supply - The pressure shall be supplied by a high-pressure pump, such as a 30,000 psig Sprague diaphragm pump, Model S-216-CPR-300. All tubing and fittings shall be high-pressure 304 or 316 stainless steel. The pump shall be capable of maintaining test oil at 0-20,000±25 psig. A diagram of the system is shown in Figure 2.

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

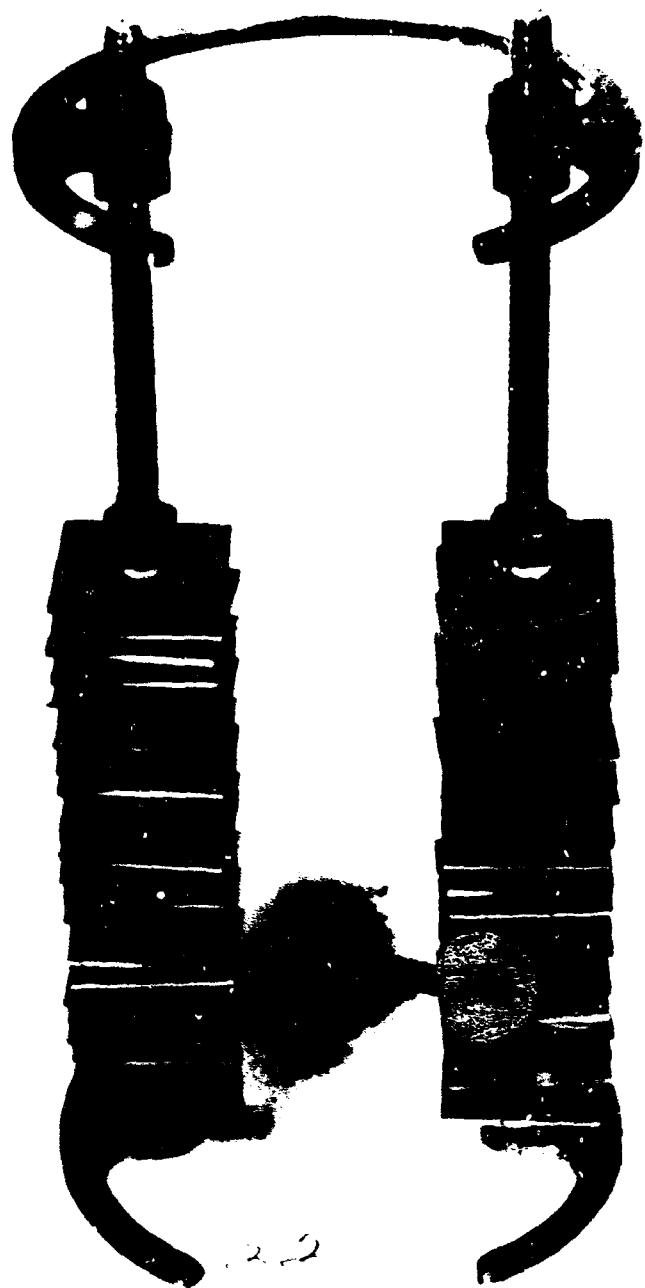


Figure 1 (C4)  
Specimen Holder and Specimens

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY

A - Air Driven Pump (rated 30,000 psig)	H - Heated Oil Bath (20 gallons, 140° F, 210°C.TEP)
B - Pump Reservoir (capacity 3 gallons)	I - Reaction Vessel (100-ml, rated 30,000 psig at 140° F)
C - Pressure Generator (30,000 psig, .11 cc)	J - Thermocouple
D - Pressure Gage (25,000 psig)	K - Marine Propeller
E - Rupture Assembly Set (22,000 psig)	L - Permanent Magnetic Drive
F - Fluid Separator (325 cc, 30,000 psig at 12° F)	
G - Support Stand (30 x 36 x 40 inches)	

All tubing - 1/4-inch OD, 1/16- or 3/32-inch ID, rated 60,000 psig.

All valves, tees, elbows - rated 30,000 psig.

All connections use superpressure fittings.

Auxiliary Equipment (Not Shown)

High-Speed Bath Stirrer

Immersion Heaters (1500 watts maximum)

Bath Temperature Control

Recording Potentiometer

Air Lines, Filters, Pressure Regulators, etc

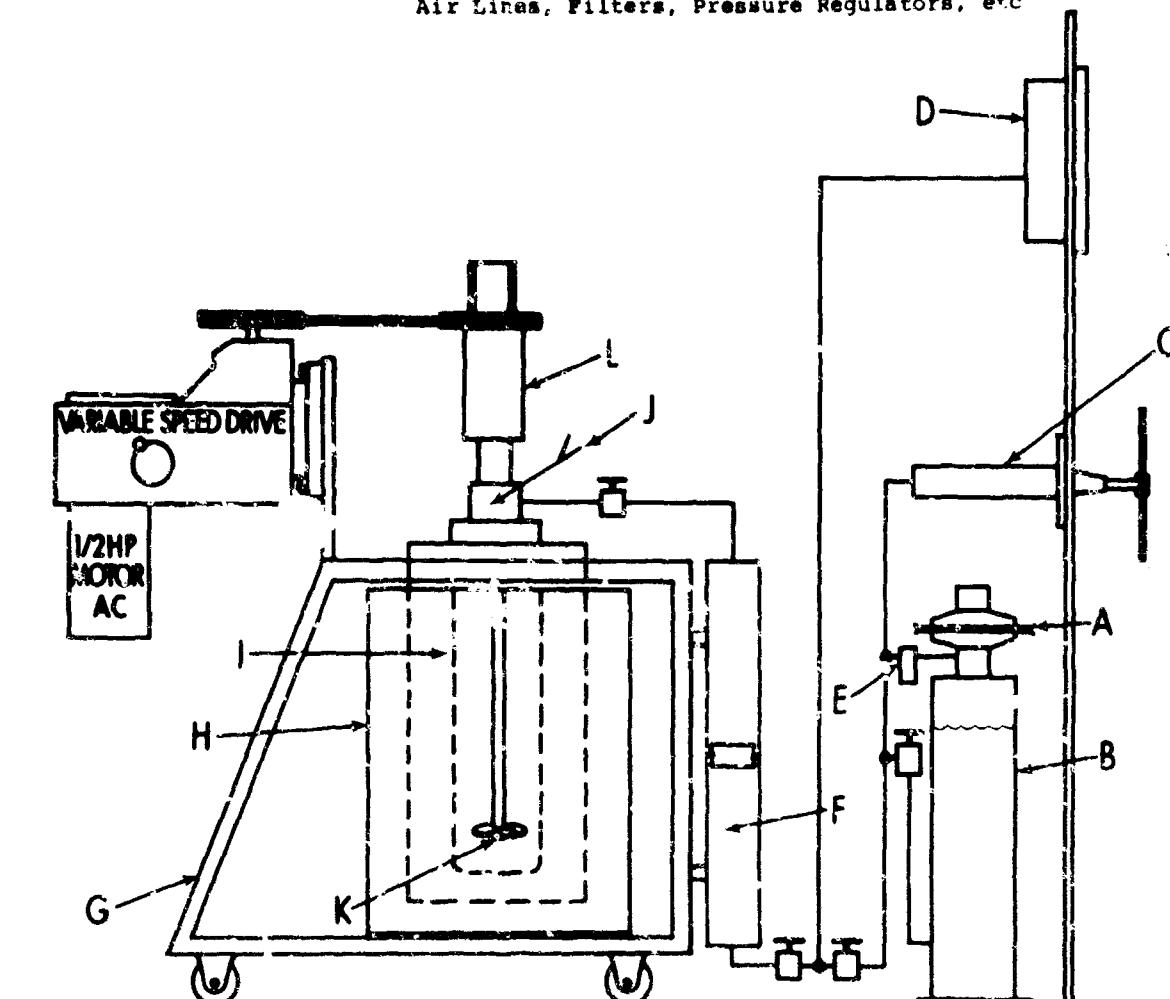


Figure 2 (C4) - Stirred Reaction Vessel for 20,000 PSIG

e. Recording potentiometer - A recording potentiometer capable of recording oil temperatures of  $100^{\circ}$ - $250^{\circ}\pm 2^{\circ}$  F shall be used.

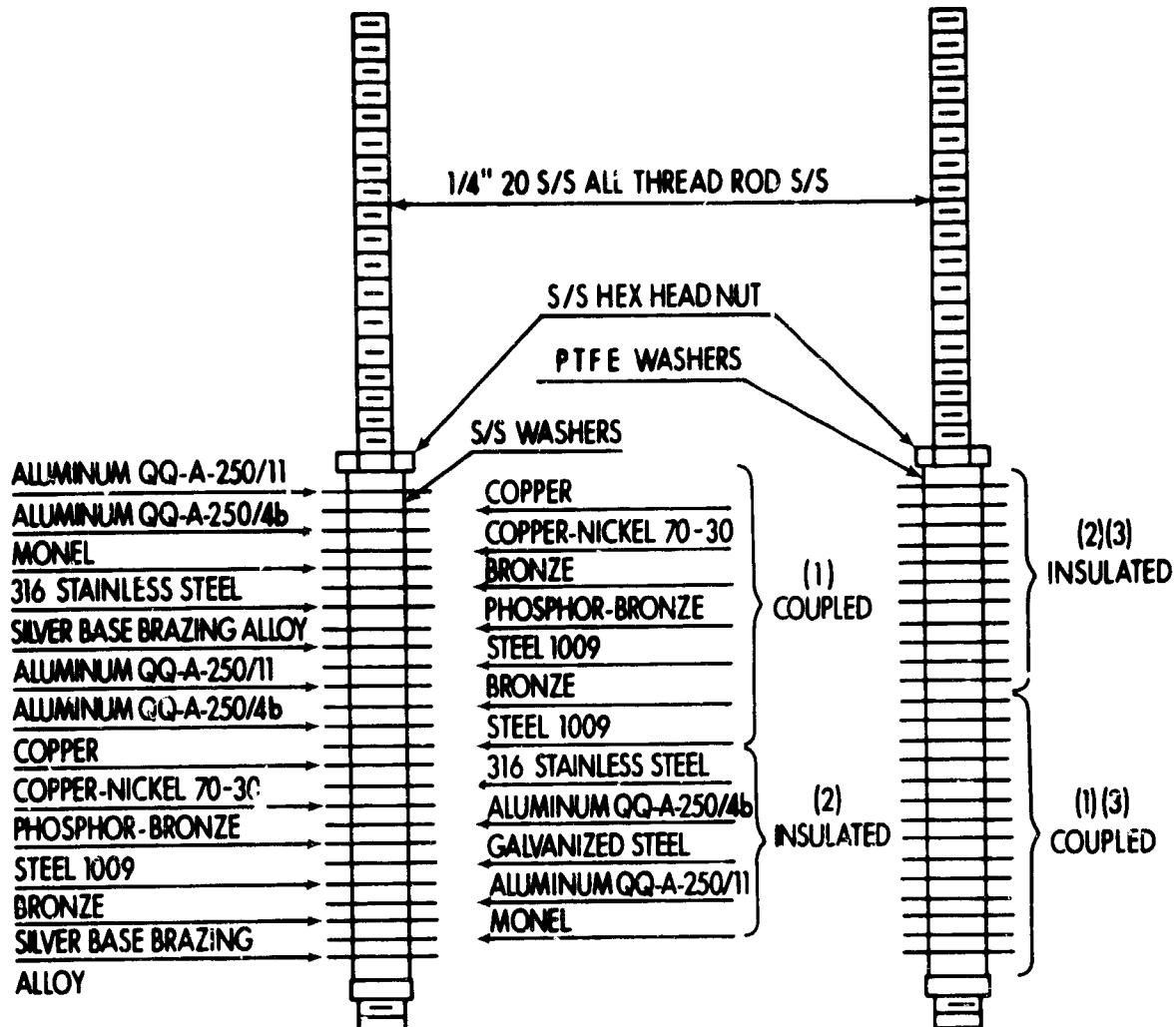
f. Corrosion specimens - The corrosion specimens shall be 1 x 1 x 0.032 inch with a 1/4-inch hole in the center. The specimen shall have a finish (before polishing) conforming to Federal Test Method Standard No. 791a, Method 5308.4. The specimens shall be of any deep submergence alloy or metal to be studied. Those used by NAVSHIPRANDBLAB Annapolis are shown below.

- (1) STEEL, Stainless, Type 316.
- (2) ALUMINUM 6061, Specification QQ-A-250-11
- (3) COPPER-NICKEL, 70-30, MIL-C-15726 or MIL-T-00/6420.
- (4) STEEL, QQ-S-698, Grade 1009.
- (5) ALUMINUM, QQ-A-250-4b.
- (6) COPPER, QQ-C-576a.
- (7) NICKEL-COPPER, QQ-N-281, Class A, Monel 400.
- (8) BRONZE, MIL-B-16541A(WEP) (1/16-inch-thick).
- (9) PHOSPHOR-BRONZE, QQ-B-750, Composition.
- (10) SILVER BASE BRAZING ALLOY, MIL-B-15395A, Grade IV.
- (11) STEEL, Galvanized, Electrodeposited, QQ-Z-325A, Type II, Class I.

A typical order of assembly of electrically coupled and insulated specimens is shown in Figure 3.

g. Spacers - Spacers for specimens shall be made of 304 stainless steel and of PTFE. They shall be cut from 1/4-inch ID, 3/8-inch OD tubing and shall be 1/8-inch-thick.

NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY



(1) 304 STAINLESS STEEL WASHERS USED FOR COUPLING COUPONS  
 (2) POLYTETRAFLUOROETHYLENE WASHERS USED FOR INSULATION  
 (3) SPECIMENS IN SAME ORDER AS OTHER ROD

Figure 3 (C4) - Specimen Assembly for Stirred Corrosion Test

## Materials

- a. Naphtha solvent - conforming to ASTM D-91.
- b. Freon TF solvent - trichlorotrifluoroethane, E. I. du Pont de Nemours and Company.
- c. Aluminum oxide polishing compound, 150 grit.
- d. Seawater ASTM D-665.
- e. PTFE tape, 1/2-inch-wide, Scotch Brand No. 48, Minnesota Mining and Manufacturing Company.
- f. Typewriter brush, Federal Specification H-B-00681C.

## Preparation of Apparatus

- a. Piping and connections shall be drained free of oil.
- b. The internal surfaces of the reaction vessel shall be wiped clean with lint free rags.
- c. The vessel shall be filled with test oil and stirred for 1 hour, then drained free of oil.
- d. Repeat a., b., and c. two additional times.
- e. Drain and fill with test oil.

## Preparation of Corrosion Specimens

- a. Handle specimens with disposable polyethylene gloves.
- b. Flush with naphtha to remove preservatives.
- c. Polish with 150 grit aluminum oxide powder on medicinal cotton wads (do not polish plated specimens).
- d. Make polishing strokes in one direction.
- e. Turn specimen 90° and polish until previous polishing marks are removed.
- f. Brush with camel hair brush.
- g. Use wash bottle to flush specimen with jet of naphtha, then a jet of Freon TF.

h. Air dry and place in desiccator.

i. Weigh on semimicrobalance, record weight to 0.00001 gram.

Preparation of Specimen Holder and Spacers - Specimen holder and spacers shall be cleaned with naphtha, soap and water, distilled water and then oven-dried at 140° F.

Procedure

a. Assembly of specimens - Handle the specimens and specimen rack with polyethylene gloves. Wrap the 1/4-inch specimen rack and rods with PTFE tape to insulate from the specimens. Place the specimens on rods in desired order. Use two PTFE spacers to prevent electrolytic contact between the specimens, or use two stainless steel spacers to form electrolytic couples between the specimens. Order of assembly is shown in Figure 3.

b. Add the test oil to the reaction vessel. (The reaction vessel remains in constant temperature bath at all times.) After the test oil is at desired temperature, soak the specimen assembly in the reaction vessel for 1 hour and securely close the reaction vessel.

c. Attach the specimen assembly to the cover. Add the desired amount of seawater. Lower the cover into the vessel.

d. Bleed off the air from the reaction vessel by pumping in excess oil.

e. Close the valves, pressurize the system, and start the stirrer.

f. The stirrer may be operated continuously or intermittently, as desired.

g. At the end of the test period the pressure is released and the specimen assembly is removed. The specimens are stored in naphtha prior to cleaning.

h. The specimens are cleaned by successive flushes with naphtha and brushing with a naphtha-wet typewriter brush.

i. A final flush with Freon TF is made, then the specimens are placed in a desiccator and weighed to obtain the gain or loss due to corrosion.

j. Record of changes in the weight and the appearance of specimen is made by written notes and photographs.

### C3. On-Off Rust Test Procedure

Scope - This method is intended to establish the ability of a fluid to prevent corrosion when contaminated with seawater under conditions of intermittent agitation.

Outline of Method and Apparatus - The ASTM D-665 method and apparatus is used except as described below. An ASTM D-665, double-blade stirrer, paragraph 9b, is used. The specimen is polished and attached to the holder using a 1/16-inch-thick, 1/2-inch-diameter PTFE gasket between specimen shoulder and holder. After the 30-minute soaking period, 150 ml of the 300-ml fluid sample is removed and 150 ml of seawater is added. The seawater is added dropwise from a burette while stirring. The burette top is just above the surface of the fluid. The seawater shall be added within 30 minutes. The oil and water sample is stirred for 15 minutes, once every 24 hours. After the first 24 hours the specimen is observed for rusting and the fluid-water emulsion examined for stability; it is then examined twice weekly during the test period. Distilled water is added at these times to make up for water lost by evaporation. The test period is 30 days. Quadruplicate determinations will be made. A fluid is considered to have satisfactory rust protection if three out of four specimens show no rust and no more than light rust is observed on the fourth specimen after 30 days.

## ELECTRICAL PROPERTY MEASUREMENT PROCEDURES

Methods of determining dielectric properties of fluids at temperatures as low as 28° F and pressures up to 20,000 psig, particularly as they are affected by seawater and carbon contamination, have not been fully developed. The following test methods, E1 through E7, are performed at room temperature and atmospheric pressure and are expected to give a good first approximation of the properties being measured. As these methods are improved and high pressure methods are developed they will be added.

## II. Resistivity

Scope - This method is intended to measure the insulating characteristics of a fluid. It determines the value of resistivity of a fluid.

Outline of Method and Apparatus - ASTM Method D1169 is used except as noted below. The fluid sample is placed in a test cell and resistivity measured with a General Radio Type 1644A megohm bridge or equivalent. The test cell may be any one of three cells described in Figure 2, 3, or 4 of the appendix to ASTM D1169 (Specific Resistance of Electrical Insulating Liquids). The temperature of the fluid is held between 65°-85° F and preferably 77±2° F. Resistivity is recorded as ohm-cm at °F. A tentative standard of acceptable resistivity for dielectric fluids has been set at  $3.0 \times 10^{11}$  ohm-cm. minimum.

## E2. Dissipation Factor

Scope - This method is intended as a measure which will be useful in predicting decreases in the efficiency of fluid immersed electrical equipment due to electrical energy losses through a fluid in an electric field in a nonsinusoidal a-c system. Specifically, the method measures the loss angle of a fluid filled cell on a capacitance bridge.

Outline of Method and Apparatus - The fluid sample is placed in a test cell of the type referred to under Test Method E1, "Resistivity". Dissipation factor is measured with a General Radio Type 1615 or 1617 capacitance bridge or the equivalent of either or these. The temperature of the fluid is held between 65°-85° F and preferably 77±2° F. Dissipation factor is recorded as percent at °F. A tentative standard of acceptable dissipation factor for dielectric fluids has been set at 5.0%, maximum.

### E3. Dielectric Breakdown Voltage

**Scope** - This method is intended to measure the ability of a fluid to withstand electrical stress. It determines the voltage at which breakdown occurs between two electrodes under prescribed conditions.

**Outline of Method and Apparatus** - ASTM D877 is used, with the following exceptions:

- a. The electrode spacing is  $0.050 \pm 0.001$  inch.
- b. Voltage rise rate is 600 volts per second  $\pm 20\%$ .
- c. Five separate readings are taken on the same sample, with a 3-minute wait between readings. The result is reported as the average of the five readings, in kilovolts.
- d. The temperature of the fluid sample should be between  $65^{\circ}$ - $85^{\circ}$  F and preferably  $77 \pm 2^{\circ}$  F. The temperature of the fluid is recorded. A convenient single package instrument for this test is a Model 4507 "Oil Testing Hypot" manufactured by Associated Research, Incorporated, Chicago, Illinois. A tentative standard of acceptable dielectric breakdown voltage for dielectric fluids has been set at 15.0 kv, minimum, at a 0.05-inch electrode gap.

#### E4. Stability of Seawater - Fluid Emulsions

Scope - This method describes a procedure for determining the stability of water dispersed in a pressure-compensating fluid in order to estimate fluid utility for electrical equipment service.

Outline of Method - Oil (100 ml) and synthetic seawater (10 ml) are stirred for 15 minutes and transferred to a 100-ml graduated cylinder. The time required for separation of synthetic seawater from the compensating fluid is recorded.

#### Apparatus

- a. Beaker, 250 ml.
- b. Mechanical stirrer as described in ASTM D179 or equivalent.
- c. Buret, 25 ml.
- d. Cylinder, graduated, 100 ml in 1-ml increments.
- e. Volt-ohmmeter capable of measuring 1 megohm and less.

#### Procedure

- a. Measure 100 ml of the test fluid into a 250-ml beaker.
- b. Add 10 ml of synthetic seawater (SSW), prepared according to ASTM D665 (IP 135), dropwise, with stirring.
- c. Stir the mixture vigorously with a mechanical stirrer, for 15 minutes.
- d. Stop the mixing and transfer the mixture immediately to a 100-ml graduated (glass) cylinder. This latter step should require about 10-20 seconds. (At this point the mixture may have completely separated into two layers, or it may be a milky emulsion.)
- e. The time required for separation of a small quantity (1/2 ml or less) of SSW is now measured as follows: Two bare 1/16-inch-diameter copper wires, connected to a volt-ohmmeter, are inserted into the graduated cylinder, touching the bottom of the cylinder. The wires are kept 1/4 to 1/2 inch apart. Separation of SSW is indicated when resistance across the wires drop to less than 0.1 megohm.

f. Stability of the emulsion is recorded as the time required for the separation of synthetic seawater, as described in e. The fluid is classified according to time required for separation. A tentative standard is as follows:

<u>Classification</u>	<u>Time Required for Water Separation</u>
A. Suitable for use with motors	5 minutes or more
B. Questionable for use with motors	1-5 minutes
C. Unsuitable for use with motors	<1 minute
D. Suitable for contactors, switches, etc	No emulsion stability requirement

## E5. Changes in Dielectric Properties Resulting from Sea-Water Contamination

**Scope** - This method describes the preparation of samples to determine the effect of sea-water contamination on the electrical properties of fluids as determined by Methods E1, E2, and E3.

**Outline of Method** - The methods described in E1, E2, and E3 are used to measure the changes in dielectric properties brought about by contamination with SSW. The effects of three concentrations, 0.1%, 0.5%, and 2.0%, are measured.

### Procedure

a. 0.1% SSW - To 400 ml of the test fluid, 0.4 ml of SSW is added dropwise, with stirring. The mixture is stirred vigorously with a mechanical stirrer (ASTM D1479) for 15 minutes, then it is allowed to stand for 5 minutes. The required sample is carefully poured (to avoid pouring out any settled water) into the appropriate test cell. Resistivity and dissipation factor are measured per Test Methods E1 and E2. The sample is then recombined with the remaining portion and the mixture is stirred vigorously for 5 minutes more. A 100-ml sample is removed, and dielectric breakdown voltage is measured per Test Procedure E3. The 100-ml sample is then discarded.

b. 0.5% SSW - The procedure of a. is repeated, except add 1.2 ml of SSW to the 300 ml of liquid remaining from a.

c. 2.0% SSW - The procedure of a. is repeated, except add 3.0 ml of SSW to the 200 ml of liquid remaining from a.

Results are reported as resistivity, dissipation factor, and dielectric breakdown voltage at the three levels of SSW contamination.

## E6. Changes in Dielectric Properties Resulting from Carbon Contamination

Scope - This method describes the preparation of samples to determine the effect of fluid contamination by finely divided carbon on the electrical properties as determined by Methods E1, E2, and E3.

Outline of Method - The methods described in E1, E2, and E3 are used to measure the changes in dielectric properties brought about by contamination by finely divided carbon which simulates brush wear or fluid degradation. The effects of three concentrations, 0.1%, 0.25%, and 0.50%, are measured.

### Procedure

a. 0.1% carbon - To 250 ml of test fluid is added 0.025 gram of "Eagle" brand lamp black, manufactured by Columbian Carbon Company, New York, New York, while stirring (ASTM D1479 stir er). After all the lampblack has been wetted by the fluid, stirring is continued vigorously for 15 minutes. Resistivity, dissipation factor, and dielectric breakdown voltage are measured on the test mixture. The sample used for the dielectric measurements (approximately 100 ml) is recombined with the remaining material prior to Step b.

b. 0.25% carbon - To the 250-ml mixture of Step a., 0.0375-gram additional lampblack is added, with stirring, and stirring is continued for 15 minutes. The procedure of Step a. is then repeated.

c. 0.50% carbon - Additional lampblack (0.0625-gram) is added and Step b. repeated.

Results are reported as resistivity, dissipation factor, and dielectric breakdown voltage at the three levels of carbon contamination.

## E7. Effects of Electrical Arcing on Fluids

Scope - This method determines the ability of a fluid to withstand the effects of electric arc discharge.

Outline of Method - The fluid is subjected to a series of arcs at a specified rate, and the electrical properties are measured by Methods E1, E2, and E3 to determine fluid property changes.

Apparatus - In addition to the apparatus required for Methods E1-E3, the following are required:

- a. Guardian Manufacturing Company Type 2110V double-pole/single-throw, normally open (D.P.S.T., N.O.) relay with silver cadmium contacts.
- b. Millipore membrane filter, diameter 47-mm pore size 0.8-micrometer or equivalent, as described in SAE Aerospace Recommended Practice, ARP 785.
- c. Power supply, 90-volt open circuit, 10-ampere closed circuit.
- d. Counter capable of recording 50,000 operations.

### Procedure

- a. The testing is carried out with a Guardian Manufacturing Company Type 2110V D.P.S.T., N.O. relay having silver-cadmium contacts. The outer covering of the coil and the adhesive material are first removed and the coil recoated with RTV silicone rubber, to minimize interaction with the test fluid.
- b. The cleaned relay is immersed in 400 ml of the test fluid at the desired test temperature. The fluid is subjected to 50,000 arcs (1 arc = 1 make + 1 break of the contacts) under a primarily resistive load with an open-circuit voltage of 90 volts and a closed-circuit current of 10 amperes. The rate of arcing is 5 to 10 arcs per minute. If the contacts fail, as indicated by arcing when closed, before 50,000 operations, they must be replaced.
- c. The following are measured and reported as indicated:
  - (1) Resistivity, dissipation factor, and dielectric breakdown voltage (see Test Methods E1-E3) initially and after 50,000 arcs.

(2) The amount of solid products generated is measured gravimetrically by the method described in SAE Aerospace Recommended Practice, ARP 785. The weight is reported in milligrams in total sample.

(3) The measurements of (1) are repeated on the filtered fluid.

NOTE: This test is to be revised when more experience is gained at higher current values.

## E8. Life of contacts in the Fluid under Pressure

Scope - This method determines the effect of fluid immersion on relay contacts subjected to high pressure.

Outline of Method - A relay is operated immersed in fluid under 6000 psi pressure to the point of failure of the electrical contacts.

Apparatus - In addition to the apparatus required for Method E7, the following will be required:

- a. Cylindrical PTFE or polyethylene container capable of containing relay immersed in fluid.
- b. Pressure vessel to pressurize fluid and relay to 6000 psi with electrical connections for relay operation under pressure.
- c. Counter to record number of cycles to failure.
- d. Power supply capable of 50 volts open circuit, 10 amperes closed circuit.

### Procedure

a. The test device used is the same as that described under Method E7, a. The relay is mounted inside a test cell having a cylindrical thin PTFE or polyethylene wall. The volume of fluid used is not critical.

b. The test cell is pressurized to 6000 psi. Arcing is then carried out a rate of five to ten operations (makes and breaks) per minute, to the failure point. A primarily resistive load is used, with an open-circuit voltage of 50 volts and a closed-circuit current of 10 amperes. Failure normally occurs by a buildup of solid products between contact surfaces, preventing circuit interruption when contacts are in the open position.

c. Since contact life varies randomly over a wide range a minimum of ten tests is desirable and the spread as well as the average value are to be reported.

NOTE: This test is to be revised when more experience is gained at higher currents and higher pressures.

CHAPTER III  
FLUID AND LUBRICANT PROPERTY VALUES, APPLICATIONS AND LIMITATIONS

This chapter provides available physical and chemical properties of fluids, suggested applications, and possible limitations of fluids for deep submergence vehicles. Where known, the estimated fluid cost is given. The tables have been prepared to provide for the addition of properties, when available, and of other fluids as they become known and applications warrant.

The possible limitations are given as a warning so that particular attention will be focused on any fluid property weakness. These limitations are based on general use of the fluid for all types of applications in a deep ocean environment.

Careful design and selection of system components may permit the use of a fluid or lubricant which would be unacceptable by the usual standards. This handbook does not consider the exceptions, but rather states the limitations as a warning. If a designer is compelled by circumstances to create an exception, these warnings should show where the design effort must be directed.

Tentative guidelines for suggested fluid uses and possible fluid limitations have been developed. They are based on the combination of application requirements, equipment developments, laboratory measurements of fluid properties, and field experience.

In systems with moving parts, the fluid depth capability is that at which pressure or temperature effects cause the viscosity to exceed 100 centistokes.

Fluid lubricating-ability criteria are based on: (1) wear-test and rolling-contact/fatigue-test performance, (2) known viscometric characteristics, and (3) known performance in operating equipment.

Corrosion protection is based on laboratory and field evidence of inertness of system ferrous and nonferrous metals, with and without sea-water contamination.

The limiting density for fluids in deep submergence vehicle applications where weight is critical is considered to be 1.0 gram per cubic centimeter.

The criteria for the fire resistance of fluids are based on the autoignition temperature of their vapors and combustion characteristics at high pressures. Fluids having ambient pressure flash points under 300° F are considered flammable.

Electrical application guidance for fluids is based on their tentative laboratory dielectric test limits given in Chapter II, on their ability to cope with intrinsic (carbon) and extrinsic (sea-water) contamination, and on their sea-water fluid emulsion stability. Critical fluid properties for each of the following uses are:

- Electric motors: initial dielectric properties, reaction to arcing (for d-c motors), heat transfer properties, emulsion stability, and compatibility with other materials.
- Switches, contactors, and circuit breakers: initial dielectric properties, heat transfer properties, reaction to arcing, and compatibility with other material.
- Stationary electrical components: initial dielectric properties, heat transfer properties, and compatibility with other materials.

Fluids for power transmission, such as hydraulic systems, must have satisfactory performance in all fluid and lubricant property categories, including dielectric properties. Fluids for mechanical elements, such as gear trains and hydraulic motors, must exhibit good lubricating properties and good corrosion inhibition while dielectric properties are less critical. Fluids for environmental protection of moving electrical components must have favorable dielectric properties, afford good corrosion inhibition, and have favorable lubricating properties with and in the absence of sea-water contamination. Fluids for environmental protection of nonmoving electrical components in sealed cases must have favorable dielectric and corrosion inhibiting properties, but here the lubricating properties are less critical.

Representative federal specification products and representative military specification products are tabulated in numerical order. Proprietary products are coded and are listed in the order in which they were received for evaluation.

The fluids are listed in Table 1 (see page III-4) for ready reference in the order as noted above, along with common designation, base fluid composition, and a listing of possible

uses with a general assessment of applicability to possible uses. The assessment of the fluid utility is based on its use for deep ocean applications. Even though a fluid may have been used successfully for aircraft, missile, or surface ship requirements, its satisfactory performance under deep ocean conditions is not assured. The symbols on the summary table are defined as follows:

- P - indicates that the fluid may be used in the listed application with normal design precautions and considerations.

- Q - indicates that the fluid has properties which make its use in the listed application questionable. It does not mean that the fluid cannot be used in the listed application. It does mean that if the fluid is used in such an application, special precautions and special design considerations must be observed. A fluid in this category may possibly be suited for short-term use only.

- K - indicates that the fluid has either been used or has been tried in the listed application.

- Blank (-) - indicates that there is insufficient available information to make any assessment of the utility of the fluid in the listed application.

In the case of a combined symbol, such as KP or KQ, the K indicates that the fluid has been tried for the use indicated, and the P or Q indicates that it is either possible or questionable, as defined above.

The listing of P after a product does not constitute endorsement for use, and the listing of Q does not constitute condemnation.

**Table 1**  
**Summary List of Fluids and Lubricants Tabulated**

Specification or Trade Name	Other Designation	Base Fluid Com- position	Application					
			Power Trans- mission	Lubri- cation	Motor Immer- sion	Switching Component Immersion	Nonmoving Electrical Equipment Immersion	
<u>Federal Specification Products</u>								
WV-1-590a	Transformer Oil	Petroleum	-	-	Q	KP	KP	
WV-D-001078 (10 cs)	Damping Fluid	Silicone	Q	Q	KQ	KQ	PP	
WV-D-001078 (50 cs)	Damping Fluid	Silicone	KQ	Q	Q	Q	Q	
<u>Military Specification Products</u>								
MIL-H-5606B	Aircraft Hydraulic Fluid	Petroleum	KP	KP	KP	P	P	
MIL-J-5624F	JP-5	Petroleum	-	KQ	KQ	Q	Q	
MIL-L-6081C, Grade 1010	Jet Engine Lubricating Oil	Petroleum	KQ	KQ	KQ	KQ	Q	
MIL-H-6083C	Aircraft Hydraulic System Preservative	Petroleum	K	KQ	KQ	KQ	KQ	
MIL-L-6085A	Aircraft Instrument Oil	Synthetic	KQ	KQ	KQ	Q	Q	
MIL-L-7808G	Gas Turbine Lubricating Oil	Synthetic	-	KQ	Q	Q	Q	
MIL-L-7870A	-	Petroleum	-	K	Q	Q	Q	
MIL-C-5188C	Gas Turbine Engine Preservative	Synthetic	KQ	KQ	Q	Q	Q	
MIL-F-17111	Ordnance Hydraulic Fluid	Petroleum	Q	P	-	-	P	
MIL-L-17672, MS 2110-TH	Turbine Oil and Hydraul- ic Fluid	Petroleum	KQ	KQ	Q	Q	P	
MIL-S-21568A	Damping Fluid	Silicone	Q	Q	KQ	KP	KP	
MIL-L-23699A	Aircraft Turboprop and Turboshaft Lubricant	Synthetic	-	KQ	-	-	-	
MIL-H-27691A	Aircraft High Tempera- ture Hydraulic Fluid	Petroleum	-	-	-	-	-	
MIL-H-46004	Missile Hydraulic Fluid	Petroleum	KQ	-	-	-	-	
MIL-H-81019B	Aircraft and Missile Hydraulic Fluid	Petroleum	P	Q	-	-	P	
<u>Proprietary Fluids</u>								
Fluid Code A	Sea-water Emulsifying Fluid, Type I	Petroleum	KQ	KQ	Q	Q	Q	
Fluid Code B	-	Petroleum	KP	KQ	Q	Q	-	
Fluid Code C	Proposed Specification MIL-H-25598 Missile Hydraulic Fluid	Petroleum	KP	KQ	Q	Q	Q	
Fluid Code D	Traction Drive Fluid	Petroleum	-	-	-	-	-	
Fluid Code E	-	Petroleum	-	KQ	KQ	-	P	
Fluid Code F	-	Petroleum	P	P	-	-	P	
Fluid Code G	-	Petroleum	P	P	-	-	P	
Fluid Code H	-	Petroleum	P	P	-	-	-	
Fluid Code J	USP Mineral Oil	Petroleum	-	Q	KQ	KQ	KP	
Fluid Code K	NF Mineral Oil	Petroleum	-	Q	-	-	-	
Fluid Code L	Lubricity Improved Silicone	Silicone	Q	Q	KQ	KP	KP	
Fluid Code M	-	Petroleum	-	P	Q	Q	Q	
Fluid Code N	Sea-water Compatible Water Glycol	Water	-	Q	Q	Q	Q	

P - Possible use

K - Known or attempted use

Q - Questionable for use in this application  
 - (blank) - Insufficient information available for  
 assessment of use

FEDERAL SPECIFICATION PRODUCTS

Suggested Uses and Possible Limitations

The oil covered by Federal Specification VV-1-530a is a petroleum-based fluid intended to serve as an insulating and cooling medium for transformers, oil switches, and circuit breakers at atmospheric pressure. The VV-1-530a fluid also can be used as an immersion medium for equipment to a depth capability of 8000 feet. The fluid lacks adequate inhibition to prevent sea-water corrosion of ferrous and nonferrous system components. Its relative lubricating ability has not yet been established. Its poor sea-water emulsion stability makes it unacceptable for use in electric motors. Good dielectric properties and intermediate viscosity make it a moderately good choice for all other electrical applications.

**Properties of WV-1-550a(1)**  
**(Petroleum Base Fluid)**

Viscometric Properties				Method
Viscosity, centistokes, at:	90° F	100° F	150° F	
0 psig	57.00	9.65	4.86	
5,000 psig	99.99	16.78	6.44	See R5101, Annapolis Report
10,000 psig	194.9	20.47	8.05	NATLAW 510
15,000 psig	299.9	30.57	11.34	-
20,000 psig	370.1	39.21	15.39	-
25,000 psig	912.0	76.67	21.60	-
30,000 psig	1916	141.5	36.21	-
Viscosity, centistokes, at 210° F.				ASTM D-240
0 psig				
Viscosity, Slope, ASTM	0.822			
Lubricating Ability				
Ball Wear Test, 30 min, 50° C., 100 steel, average scar dia., mm:				ASTM D-414 (modified)
1 kg				-
3 kg				-
5 kg				-
Rolling Contact Fatigue Test				
Life to 10% Failure				MIL-H-10457
Life to 50% Failure				
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 1 Test C-9
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 1 Test C-1
Copper	-54.5			-
Stainless Steel, 316	+3.2			-
Copper-Nickel (70-30)	+2.1			-
Aluminum, QQ-A-250-4b	-124.2			-
Phosphor-Bronze	-61.3			-
Steel, galvanized	-46.9			-
Steel, 1009	-547.5			-
Aluminum, QQ-A-250-11	+4.3(2)			-
Bronze	-11.8			-
Monel	+3.1			-
Silver Base Brazing Alloy	-14.3			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 1 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

Method					
<u>Corrosion Protection (Cont.)</u>					
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Braze Alloy -	-				
Steel, 1004	-				
Aluminum QQ-A-250-11 -	-				
Bronze	-				
Aluminum QQ-A-250-4b -	-				
Steel, 1009	-				
<u>20,000 PSIG Stirred Corrosion Test, weight change, mg</u>	See Chapter 2				
<u>Insulated Specimens:</u>	Test C-4				
Copper	-				
Stainless Steel, 316	-				
Copper-Nickel (70-30)	-				
Aluminum, QQ-A-250-4b	-				
Phosphor-Bronze	-				
Steel, galvanized	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11	-				
Bronze	-				
Monel	-				
Silver Base Braze Alloy	-				
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum, QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Braze Alloy -	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11 -	-				
Bronze	-				
Aluminum, QQ-A-250-4b -	-				
Steel, 1009	-				
<u>Pump Test</u>	Proposed military specification for sea-water emulsifying oils				
<u>Average Weight Loss, mg</u>					
Steel Gears	-				
Bronze Bushings	-				
<u>Corrosion Coupons, weight loss, each, mg/cm<sup>2</sup></u>					
Copper	-				
Aluminum	-				
Steel, galvanized	-				
Steel, 1009	-				
Silver Base Braze Alloy	-				
<u>Dielectric Properties</u>					
<u>Resistivity, 78° F, ohm-cm:</u>					
As-Received	$5.2 \times 10^{13}$				
With Sea-Water Contamination: (3)	$15.0 \times 10^{13}$				
0.5% by volume	-				
2.0% by volume	-				
<u>With Carbon Contamination:</u>					
0.1% wt/vol.	See Chapter 2				
0.25% wt/vol.	Test E-5				
0.5% wt/vol.	-				

After 10,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resis- tive load				See Chapter 2 Test E-7
Not filtered	3.4x10 <sup>15</sup>			-
Filtered	1.0x10 <sup>14</sup>			-
Solids generated, gram	1.0			See Chapter 2 Test E-2
Dielectric Factor, 73° F.				See Chapter 2 Test E-5
As-Received	1.0			-
With Sea-Water Contamination: (3)	0.5			See Chapter 2 Test E-6
0.1% by volume				-
2.0% by volume				-
With Carbon Contamination:				-
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resis- tive load				-
Not filtered	1.0			-
Filtered	0.6			-
Solids generated, gram				ASTM D-877 (mod- ified). See Chap- ter 2. Test E-3
Dielectric Breakdown Voltage, 0.06-inch gap, 73° F, kv				See Chapter 2 Test E-5
As-Received	25.0			-
With Sea-Water Contamination: (3)	8.9			-
0.1% by volume				-
2.0% by volume				-
With carbon contamination:				See Chapter 2 Test E-6
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resis- tive load				-
Not filtered	10.1			-
Filtered	22.4			-
Solids generated, gram				See Chapter 2 Test E-8
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				-
Number of tests	4			-
Operations to failure (range)	4-300			-
<u>Emulsion Stability</u>				ASTM D-1401
Paddle Test, after 1-hour set- tling:				-
Oil, ml	40			-
Emulsion, ml	0			-
Water, ml	40			-
Electric Probe Test, time for water separation, min	0.2			See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI*</u>				See Chapter 2 Test C-3
Butyl	Poor			-
Buna N	Good			-
Viton B	Good			-
Ethylene-Propylene	Poor			-
Tetrafluoroethylene (Teflon)	Good			-
Neoprene	Fair			-
Thiokol				-
Silicone	Fair			-
Fluorosilicone	Fair			-

\*Based on atmospheric pressure data.

Method			
<u>Volatility</u>			
<u>Toxicity</u>	Petroleum		
<u>Density, grams/cubic centimeter, at:</u>	35° F	100° F	190° F
0 psig	0.8947	0.8700	0.8511
5,000 psig	0.8937	0.8804	0.8636
10,000 psig	0.8935	0.8868	0.8711
15,000 psig	0.8916	0.9006	0.8871
20,000 psig	0.8923	0.9122	0.8999
	0.8921	0.9174	0.9103
<u>Isothermal Compressibility, volume decrease, %, at:</u>	35° F	90° F	110° F
0 psig			
5,000 psig	1.00	1.12	1.45
10,000 psig	1.61	1.84	2.50
15,000 psig	2.42	2.73	3.41
20,000 psig	2.92	3.29	4.06
	4.03	4.50	5.53
	5.03	5.23	6.50
<u>Chemical Stability</u>			
<u>Oxidation Stability Test, 203° F, hours to failure</u>			ASTM D-943
<u>Oxidation Stability Test, 250° F</u>			
<u>Hydrolytic Stability Test</u>			
Specimen change, mg			Fed. Method 5208
Specimen appearance			Military specification MIL-H-19457B
Fluid acid number increase, mg KOH/gram fluid			-
Water acidity, mg KOH			-
Insolubles, %			-
<u>Thermal Stability Test</u>			-
<u>Fire Resistance</u>			-
Flash Point, °F	325		ASTM D-92
Fire Point, °F	345		ASTM D-92
Autogeneous Ignition Temperature, °F			ASTM D-215
<u>High-Pressure Spray Combustor</u>			See MIL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F			-
Minimum reaction temperature, °F			-
No indication of fire, °F			-
Maximum pressure change, psi			-
Lowest temperature of maximum pressure change, °F			-
Temperature range explored, °F			-
<u>Miscellaneous Properties</u>			
Pour Point, °F	<40		ASTM D-97
Foaming Tendency, 75° F			ASTM D-870
Foam after 5-minute aeration, ml	<10		-
Time out, minutes	0		-
Foam after 10-minute settling, ml			-
Neutralization Number, mg KOH/gram	0.01		ASTM D-1744
Water Content, % by weight	0.007		Fed. Method 5111
Neutrality, qualitative	Neutral		-
Contamination			SAE Method ARP-608
Number and size of particles and fibers in 100-ml fluid			-
25-100 micrometers			-
100-500 micrometers			-
over 500 micrometers			-
particles over 250 micrometers except fibers (length ten times diameter)			-
Gravimetric Value, mg/100 ml			SAE Method ARP-720
Color			ASTM D-1140
Cost, \$/gal	\$ .70		-
Availability	Govt spec		-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>2</sup>Heavy deposits indicate corrosion not shown by weight change. <sup>3</sup>Saturated with seawater.

Supplementary Properties of VV-1-530a

<u>Material Compatibility with*</u>		<u>Method</u>
Buna S	Poor	See Chapter 2
Natural Rubber	Poor	Test C-3
Polyurethane	Good	
<u>Miscellaneous Properties</u>		
Specific Gravity at 60/60° F	0.88	ASTM D-1298

\* Based on atmospheric pressure data.

vv-d-001078 (10 cs)

Suggested Uses and Possible Limitations

The fluid covered by Federal Specification VV-D-001078 is a dimethyl polysiloxane developed for use as a damping fluid and is available in viscosities from 0.65 to 200,000 centistokes. The VV-D-001078, 10-cs fluid can be used as an immersion medium for nonmoving equipment and has a depth capability of 16,000 feet. It has poor sea-water corrosion inhibition capability. Its high compressibility must be considered in system design. The poor lubricating ability (particularly with steel-on-steel components) of silicone fluids limits its application to nonmoving components. Although this fluid has been used in deep submergence electrical applications, it is considered a questionable choice for electrical usage because of borderline dielectric breakdown voltage.

Properties of VV-D-001078 (10 cs)<sup>(1)</sup>  
(Silicone Fluid)

				Method
<u>Viscometric Properties</u>				
Viscosity, centistokes, at:	35° F	100° F	140° F	
0 psig	17.86	8.66	4.75	
5,000 psig	25.67	12.57	8.30	
10,000 psig	31.98	14.99	10.11	
15,000 psig	44.45	20.16	12.63	
20,000 psig	49.44	23.82	15.00	
	78.64	35.52	21.90	
	123.5	51.12	30.55	
Viscosity, centistokes, at 210° F, 0 psig	3.76			ASTM D-445
Viscosity Slope, ASTM	0.430			
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				Ref. Method 6905 (modified)
1 kg				-
3 kg				-
5 kg				-
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-1.7			-
Stainless Steel, 316	+7.7			-
Copper-Nickel (70-30)	+14.2			-
Aluminum, QQ-A-250-4b	-198.9			-
Phosphor-Bronze	-63.4			-
Steel, galvanized	-97.6			-
Steel, 1009	-1009.8			-
Aluminum, QQ-A-250-11	+210.9			-
Bronze	-1.4			-
Monel	+11.3			-
Silver Base Brazing Alloy	+19.2			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				

					Method
<b>Corrosion Protection (Cont)</b>					
Electrically Coupled Specimens:					-
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Brazing Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 PSI G Stirred Corrosion					See Chapter 2 Test C-4
Test, weight change, mg					
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Brazing Alloy					-
Electrically Coupled Specimens:					-
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Brazing Alloy -					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
Pump Test					Proposed military specification for sea-water emulsi- fying oils
Average Weight Loss, mg					
Steel Gears					-
Bronze Bushings					-
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					
Copper					-
Aluminum					-
Steel, galvanized					-
Steel, 1009					-
Silver Base Brazing Alloy					-
<b>Dielectric Properties</b>					
Resistivity, 80° F, ohm-cm:					ASTM D-1169 (mod- ified). See Chap- ter 2. Test E-1
As-Received	3.6x10 <sup>14</sup>				
With Sea-Water Con- tamination: <sup>(2)</sup>	8.6x10 <sup>13</sup>				See Chapter 2 Test E-5
0.5% by volume					-
2.0% by volume					-
With Carbon Con- tamination:					See Chapter 2 Test E-6
0.25% wt/vol.					-
0.5% wt/vol.					-

Dielectric Properties (cont)		Method				
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram					See Chapter 2 Test E-7
Dissipation Factor, 80° F, %	As-Received With Sea-Water Contamination: <sup>(2)</sup> 0.1% by volume 2.0% by volume	0.0 0.7				See Chapter 2 Test E-2
With Carbon Contamination: 0.10% wt/vol. 0.1% wt/vol. 0.50% wt/vol.						See Chapter 2 Test E-5
After 10,000 electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram					See Chapter 2 Test E-6
Dielectric Breakdown Voltage, 0.05-inch gap, 80° F, kv	As received With sea-water con- tamination: <sup>(2)</sup> 0.5% by volume 2.0% by volume	14.8 5.8				ASTM D-877 (mod- ified). See Chap- ter 2, Test E-3
With carbon contamination: 0.10% wt/vol. 0.2% wt/vol. 0.50% wt/vol.						See Chapter 2 Test E-5
After 10,000 electric (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram					See Chapter 2 Test E-6
Contact Life, silver-cadmium, 10 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F	Number of tests					See Chapter 2 Test E-8
Operations to failure (rank)						
Emulsion Stability	Paddle Test, after 1-hour set- tling:					ASTM D-1401
	Oil, ml	40				
	Emulsion, ml	0				
	Water, ml	40				
Electric Probe Test, time for water separation, min		0				See Chapter 2 Test E-4
Material Compatibility Static ECPsi*						See Chapter 2 Test C-3
Butyl	Poor-Fair					
Buna N	Fair					
Viton B	Good					
Ethylene-Propylene	-					
Tetrafluoroethylene (Teflon)	Good					
Neoprene	Fair					
Thiokol	Good					
Silicone	Poor					
Fluorosilicone	Poor					

\* Based on atmospheric pressure data.

Volatility		Silicone	100° F	150° F	Method
Toxicity					
Density, grams/cubic centimeter, at:	35° F	0.9572	0.9238	0.8973	
0 psig		0.9788	0.9514	0.9315	
5,000 psig		0.9924	0.9663	0.9484	
10,000 psig		1.0095	0.9859	0.9708	
15,000 psig		1.0062	0.9976	0.9831	
20,000 psig		1.0892	1.0206	1.0092	
20,000 psig		1.1093	1.0404	1.0314	
Isothermal Compressibility, volume decrease, %, at:	35° F	90° F	150° F		
0 psig		1.88	2.11	2.62	
5,000 psig		2.97	3.38	4.02	
10,000 psig		4.40	4.95	5.72	
15,000 psig		5.21	5.82	6.75	
20,000 psig		5.98	7.66	8.74	
20,000 psig		8.49	9.22	10.51	
Chemical Stability					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 150° F					
Hydrolytic Stability Test					
Specimen change, mg					Fed. Method 5308
Specimen appearance					Military specification MIL-H-19457B
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
Fire Resistance					
Flash Point, °F	355				ASTM D-92
Fire Point, °F	415				ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combustor					See MEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
Miscellaneous Properties					
Pour Point, °F	<65				ASTM D-97
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml	0				-
Time out, minutes	-				-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-974
Water Content, % by weight	0.010				ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Color					ASTM D-1500
Cost, \$/gal	\$20.00				-
Availability	Govt spec				-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>2</sup>Saturated with seawater.

## Supplementary Properties of VV-B-001078 (10 cs)

<u>Material Compatibility with:</u> Buna S Polyurethane	Poor Fair 0.941	<u>Method</u> See Chapter 2 Test C-3
<u>Miscellaneous Properties</u> Specific Gravity at 60/60° F		

\* Based on atmospheric pressure data.

Suggested Uses and Possible Limitations

The fluid covered by Federal Specification VV-D-001078 in the 50-cs viscosity has been used in the missile hold-down system in submarines. The VV-D-001078, 50-cs silicone fluid can be used as an immersion medium for equipment to a depth capability of 1000 feet. The fluid lacks adequate sea-water corrosion inhibition. Its high compressibility must be considered in system design. The poor lubricating ability (particularly with steel-on-steel components) limits its use. Due to a low dielectric breakdown voltage and poor sea-water emulsion stability and relatively high viscosity, this fluid is not recommended for any electrical applications.

Properties of RV-D-6010/8 (50 CS)  
(Silicone Fluid)

				Method
	40° F	120° F	170° F	
<u>Viscometric Properties</u>				
Viscosity, centistokes, at:				
0 psig				See NSKDC Annapolis Report MATLAB 50
5,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
25,000 psig				-
30,000 psig				-
35,000 psig				-
40,000 psig				-
45,000 psig				-
50,000 psig				-
55,000 psig				-
60,000 psig				-
65,000 psig				-
70,000 psig				-
75,000 psig				-
80,000 psig				-
85,000 psig				-
90,000 psig				-
95,000 psig				-
100,000 psig				-
105,000 psig				-
110,000 psig				-
115,000 psig				-
120,000 psig				-
125,000 psig				-
130,000 psig				-
135,000 psig				-
140,000 psig				-
145,000 psig				-
150,000 psig				-
155,000 psig				-
160,000 psig				-
165,000 psig				-
170,000 psig				-
175,000 psig				-
180,000 psig				-
185,000 psig				-
190,000 psig				-
195,000 psig				-
200,000 psig				-
205,000 psig				-
210,000 psig				-
215,000 psig				-
220,000 psig				-
225,000 psig				-
230,000 psig				-
235,000 psig				-
240,000 psig				-
245,000 psig				-
250,000 psig				-
255,000 psig				-
260,000 psig				-
265,000 psig				-
270,000 psig				-
275,000 psig				-
280,000 psig				-
285,000 psig				-
290,000 psig				-
295,000 psig				-
300,000 psig				-
305,000 psig				-
310,000 psig				-
315,000 psig				-
320,000 psig				-
325,000 psig				-
330,000 psig				-
335,000 psig				-
340,000 psig				-
345,000 psig				-
350,000 psig				-
355,000 psig				-
360,000 psig				-
365,000 psig				-
370,000 psig				-
375,000 psig				-
380,000 psig				-
385,000 psig				-
390,000 psig				-
395,000 psig				-
400,000 psig				-
405,000 psig				-
410,000 psig				-
415,000 psig				-
420,000 psig				-
425,000 psig				-
430,000 psig				-
435,000 psig				-
440,000 psig				-
445,000 psig				-
450,000 psig				-
455,000 psig				-
460,000 psig				-
465,000 psig				-
470,000 psig				-
475,000 psig				-
480,000 psig				-
485,000 psig				-
490,000 psig				-
495,000 psig				-
500,000 psig				-
505,000 psig				-
510,000 psig				-
515,000 psig				-
520,000 psig				-
525,000 psig				-
530,000 psig				-
535,000 psig				-
540,000 psig				-
545,000 psig				-
550,000 psig				-
555,000 psig				-
560,000 psig				-
565,000 psig				-
570,000 psig				-
575,000 psig				-
580,000 psig				-
585,000 psig				-
590,000 psig				-
595,000 psig				-
600,000 psig				-
605,000 psig				-
610,000 psig				-
615,000 psig				-
620,000 psig				-
625,000 psig				-
630,000 psig				-
635,000 psig				-
640,000 psig				-
645,000 psig				-
650,000 psig				-
655,000 psig				-
660,000 psig				-
665,000 psig				-
670,000 psig				-
675,000 psig				-
680,000 psig				-
685,000 psig				-
690,000 psig				-
695,000 psig				-
700,000 psig				-
705,000 psig				-
710,000 psig				-
715,000 psig				-
720,000 psig				-
725,000 psig				-
730,000 psig				-
735,000 psig				-
740,000 psig				-
745,000 psig				-
750,000 psig				-
755,000 psig				-
760,000 psig				-
765,000 psig				-
770,000 psig				-
775,000 psig				-
780,000 psig				-
785,000 psig				-
790,000 psig				-
795,000 psig				-
800,000 psig				-
805,000 psig				-
810,000 psig				-
815,000 psig				-
820,000 psig				-
825,000 psig				-
830,000 psig				-
835,000 psig				-
840,000 psig				-
845,000 psig				-
850,000 psig				-
855,000 psig				-
860,000 psig				-
865,000 psig				-
870,000 psig				-
875,000 psig				-
880,000 psig				-
885,000 psig				-
890,000 psig				-
895,000 psig				-
900,000 psig				-
905,000 psig				-
910,000 psig				-
915,000 psig				-
920,000 psig				-
925,000 psig				-
930,000 psig				-
935,000 psig				-
940,000 psig				-
945,000 psig				-
950,000 psig				-
955,000 psig				-
960,000 psig				-
965,000 psig				-
970,000 psig				-
975,000 psig				-
980,000 psig				-
985,000 psig				-
990,000 psig				-
995,000 psig				-
1000,000 psig				-
1005,000 psig				-
1010,000 psig				-
1015,000 psig				-
1020,000 psig				-
1025,000 psig				-
1030,000 psig				-
1035,000 psig				-
1040,000 psig				-
1045,000 psig				-
1050,000 psig				-
1055,000 psig				-
1060,000 psig				-
1065,000 psig				-
1070,000 psig				-
1075,000 psig				-
1080,000 psig				-
1085,000 psig				-
1090,000 psig				-
1095,000 psig				-
1100,000 psig				-
1105,000 psig				-
1110,000 psig				-
1115,000 psig				-
1120,000 psig				-
1125,000 psig				-
1130,000 psig				-
1135,000 psig				-
1140,000 psig				-
1145,000 psig				-
1150,000 psig				-
1155,000 psig				-
1160,000 psig				-
1165,000 psig				-
1170,000 psig				-
1175,000 psig				-
1180,000 psig				-
1185,000 psig				-
1190,000 psig				-
1195,000 psig				-
1200,000 psig				-
1205,000 psig				-
1210,000 psig				-
1215,000 psig				-
1220,000 psig				-
1225,000 psig				-
1230,000 psig				-
1235,000 psig				-
1240,000 psig				-
1245,000 psig				-
1250,000 psig				-
1255,000 psig				-
1260,000 psig				-
1265,000 psig				-
1270,000 psig				-
1275,000 psig				-
1280,000 psig				-
1285,000 psig				-
1290,000 psig				-
1295,000 psig				-
1300,000 psig				-
1305,000 psig				-
1310,000 psig				-
1315,000 psig				-
1320,000 psig				-
1325,000 psig				-
1330,000 psig				-
1335,000 psig				-
1340,000 psig				-
1345,000 psig				-
1350,000 psig</				

Method					
<u>Corrosion Protection (Cont.)</u>					
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1004	-				
Aluminum QQ-A-250-11 -	-				
Bronze	-				
Aluminum QQ-A-250-4b -	-				
Steel, 1009	-				
<u>20,000 PSIG Stirred Corrosion</u>					See Chapter 2
<u>Test, weight change, mg</u>					Test C-4
<u>Insulated Specimens:</u>					
Copper	-				
Stainless Steel, 316	-				
Copper-Nickel (70-30)	-				
Aluminum, QQ-A-250-4b	-				
Phosphor-Bronze	-				
Steel, galvanized	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11	-				
Bronze	-				
Monel	-				
Silver Base Brazing Alloy	-				
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum, QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11 -	-				
Bronze	-				
Aluminum, QQ-A-250-4b -	-				
Steel, 1009	-				
<u>Pump Test</u>					Proposed military specification for sea-water emulsifying oils
<u>Average Weight Loss, mg</u>					
Steel Gears	-				
Braze Bushings	-				
<u>Corrosion Coupons, weight loss, each, mg/cm<sup>2</sup></u>					
Copper	-				
Aluminum	-				
Steel, galvanized	-				
Steel, 1009	-				
Silver Base Brazing Alloy	-				
<u>Dielectric Properties</u>					ASTM D-1165 (modified). See Chapter 2, Test E-1
<u>Resistivity, 77° F, ohm-cm:</u>					
As-Received	7.8x10 <sup>13</sup>				
With Sea-Water Contamination,(2)	14.4x10 <sup>13</sup>				
0.5% by volume	-				
2.0% by volume	-				
<u>With Carbon Contamination:</u>					See Chapter 2
0.1% wt/vol.	-				Test E-5
0.25% wt/vol.	-				
0.5% wt/vol.	-				
					See Chapter 2
					Test E-6

				Method	
<u>Dielectric Properties (Cont.)</u>					
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				See Chapter 2 Test E-7	
Not filtered				-	
Filtered				-	
Solids generated, gram				-	
DISSIPATION Factor, 77° F, %				See Chapter 2	
As-Received	0.0			Test E-2	
With Sea-Water Contamination;(2)	0.9			See Chapter 2	
0.1% by volume				Test E-5	
2.0% by volume				-	
With Carbon Contamination:				-	
0.10% wt/vol.				See Chapter 2	
0.25% wt/vol.				Test E-6	
0.50% wt/vol.				-	
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-	
Not filtered				-	
Filtered				-	
Solids generated, gram				-	
Dielectric Breakdown Voltage, 0.06-inch gap, 77° F, kv				ASTM D-877 (mod- ified). See Chap- ter 2, Test E-3	
as received	6.3			See Chapter 2	
With sea-water con- tamination;(2)	6.1			Test E-5	
0.5% by volume				-	
2.0% by volume				-	
With carbon contamination:				See Chapter 2	
0.10% wt/vol.				Test E-6	
0.25% wt/vol.				-	
0.50% wt/vol.				-	
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-	
Not filtered				-	
Filtered				-	
Solids generated, gram				-	
Contact Life, silver-cadmium, 90 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				See Chapter 2	
Number of tests				Test E-8	
Operations to failure (range)				-	
<u>Emulsion Stability</u>					
Paddle Test, after 1-hour set- tling:				ASTM D-1401	
Oil, ml	40			-	
Emulsion, ml	0			-	
Water, ml	40			-	
Electric Probe Test, time for water separation, min	3			See Chapter 2	
<u>Material Compatibility Static 20KPSI*</u>				Test E-4	
Butyl	Poor-Fair			See Chapter 2	
Buna N	Fair			Test C-3	
Viton B	Good			-	
Ethylene-Propylene	-			-	
Tetrafluoroethylene (Teflon)	Good			-	
Neoprene	Fair			-	
Thiokol	Good			-	
Silicone	Poor			-	
Fluorosilicone	Poor			-	

\* Based on atmospheric pressure data.

<u>Volatility</u>		<u>Silicone</u>	<u>Method</u>		
<u>Toxicity</u>			35° F	100° F	140° F
<u>Density, grams/cubic centimeter, at:</u>					
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, at:</u>					
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-343 <sup>1</sup>
Oxidation Stability Test, 250° F					Fed. Method 1302
Hydrolytic Stability Test					Military specification MIL-H-19417B
Specimen change, mg					-
Specimen appearance					-
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
<u>Fire Resistance</u>					
Flash Point, °F					ASTM D-92
Fire Point, °F					ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combustor					See MEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Pour Point, °F					ASTM D-97
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-974
Water Content, % by weight					ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Color					ASTM D-1400
Cost, \$/gal		\$15.00			-
Availability		Govt spnd			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>2</sup>Saturated with seawater.

Supplementary Properties of VV-D-001078 (50 CS)

Material Compatibility with*		Method
Buna S Polyurethane	Poor Fair	See Chapter 11 Test C-5
Miscellaneous Properties Specific Gravity, 60/60° F	0.961	ASTM D-1293

\* Based on atmospheric pressure data.

MILITARY SPECIFICATION PRODUCTS

III-25

MIL-H-5606B

Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-H-5606B is a petroleum-base, low-viscosity fluid which has been used extensively in aircraft and missile hydraulic systems. The properties of MIL-H-5606B indicate that it is suitable for use as hydraulic fluid, as a motor immersion fluid, as a general lubricant, and for environmental protection of electrical equipment at depth capability of 20,000 feet. Its limitations are lack of corrosion protection, poor sea-water compatibility, and its high flammability. There are reported field application failures due to formation of large carbon deposits under pressure in electric arcing conditions; however, this problem is common to all hydrocarbon fluids. (See Chapter I.) Its combination of good sea-water emulsion stability, good dielectric properties, and intermediate viscosity makes this fluid the best choice known to date for electric motor usage and a moderately good choice for all other electrical applications.

Properties of MIL-H-5606B(1)  
(Petroleum Base Fluid)

				Method
<u>Viscometric Properties</u>				
Viscosity, high shear, cs, at:	50° F	100° F	150° F	
0 psig	29.85	12.26	7.21	
3,000 psig	43.44	16.31	9.74	See NSRDL
5,000 psig	52.89	19.21	11.39	Annapolis Report
8,000 psig	76.16	24.90	14.24	MATLAB 550
10,000 psig	92.62	29.32	16.07	-
15,000 psig	152.8	42.90	22.88	-
20,000 psig	264.4	62.55	31.65	-
Viscosity, low shear, cs, at:	50° F	100° F	150° F	
0 psig	40.50	13.80	8.60	
3,000 psig	60.55	18.39	11.53	
5,000 psig	86.66	21.87	14.01	
8,000 psig	113.4	32.33	18.82	
10,000 psig	147.1	38.78	23.53	
15,000 psig	270.5	58.41	35.07	
20,000 psig	504.8	92.59	52.58	
Viscosity, centistokes, at 210° F,				ASTM D-446
0 psig	5.16	-	-	
Viscosity Slope, ASTM	0.457	-	-	-
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:				Fed. Method 650 <sup>1</sup> (modified)
1 kg				-
3 kg				-
5 kg	0.19	-	-	-
Rolling Contact Fatigue Test, hrs:				
B10 life: Dry	34.9			
With 1% synthetic seawater	12.7			
B50 life: Dry	94.3			
With 1% synthetic seawater	35.8(4)			
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg	-			See Chapter 2 Test C-1
Copper	-4.1			-
Stainless Steel, 316	+0.1			-
Copper-Nickel (70-30)	+0.1			-
Aluminum, QQ-A-250-4b	+0.7			-
Phosphor-Bronze	+0.2(2)			-
Steel, galvanized	-116.5			-
Steel, 1009	-110.8			-
Aluminum, QQ-A-250-11	+0.6			-
Bronze	+2.1			-
Monel	+0.2			-
Silver Base Brazing Alloy	-0.7			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg	-			See Chapter 2 Test C-2
Insulated Specimens:				
Copper	-0.2			-
Stainless Steel, 316	+0.1			-
Copper-Nickel (70-30)	+0.1			-
Aluminum, QQ-A-250-4b	0			-
Phosphor-Bronze	-0.2			-
Steel, galvanized	+0.3			-
Steel, 1009	+0.1			-
Aluminum, QQ-A-250-11	+0.1			-
Bronze	0			-
Monel	0			-
Silver Base Brazing Alloy	0			-

				Method
<b>Corrosion Protection (Cont.)</b>				
<b>Electrically Coupled Specimens:</b>				-
Copper-Aluminum, QQ-A-250-11	+0.2	-0.1		-
Aluminum QQ-A-250-4b -	+0.2	0		-
Copper-Nickel (70-30)				-
Monel-Bronze	+0.1	+0.2		-
Stainless Steel (316) -	+0.2	0		-
Phosphor-Bronze				-
Silver Base Brazing Alloy -	0	+0.2		-
Steel, 1004				-
Aluminum QQ-A-250-11 -	+0.1	+0.2		-
Bronze				-
Aluminum QQ-A-250-4b -	+0.2	+0.1		-
Steel, 1009				-
<b>10,000 PSIG Stirred Corrosion Test, weight change, mg</b>				See Chapter 2 Test C-4
<b>Insulated Specimens:</b>				
Copper	-2.6			-
Stainless Steel, 316	0			-
Copper-Nickel (70-30)	0			-
Aluminum, QQ-A-250-4b	-1.9			-
Phosphor-Bronze	-2.1			-
Steel, galvanized	-0.1			-
Steel, 1009	-18.8			-
Aluminum, QQ-A-250-11	-0.1			-
Bronze	-2.5			-
Monel	0			-
Silver Base Brazing Alloy	-0.4			-
<b>Electrically Coupled Specimens:</b>				
Copper-Aluminum, QQ-A-250-11	-2.0	+0.1		-
Aluminum, QQ-A-250-4b -	+0.2	0		-
Copper-Nickel (70-30)				-
Monel-Bronze	+0.2	-2.6		-
Stainless Steel (316) -	+0.1	-3.1		-
Phosphor-Bronze				-
Silver Base Brazing Alloy -	-0.3	-11.1		-
Steel, 1009				-
Aluminum, QQ-A-250-11 -	+0.2	-2.7		-
Bronze				-
Aluminum, QQ-A-250-4b -	-0.6	-15.4		-
Steel, 1009				-
<b>Pump Test</b>				
<b>Average Weight Loss, mg</b>				
Steel Gears	15			
Bronze Bushings	9			
<b>Corrosion Coupons, weight loss, each, mg/cm<sup>2</sup></b>				
Copper	0.01			-
Aluminum	0.04			-
Steel, galvanized	0.01			-
Steel, 1009	0.03			-
Silver Base Brazing Alloy	0.02			-
<b>Dielectric Properties</b>				
<b>Resistivity, 77° F, ohm-cm:</b>				ASTM D-1164 (modified). See Chapter 1, Test E-1
As-Received	5.0x10 <sup>12</sup>			
With Sea-Water Contamination (3)	2.6x10 <sup>12</sup>			See Chapter 2 Test E-5
0.5% by volume				-
2.0% by volume				-
With Carbon Contamination:				
0.1% wt. vol.				See Chapter 2 Test E-6
0.25% wt. vol.				-
0.5% wt. vol.				-

						Method	
<u>Dielectric Properties (Cont)</u>							
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load							See Chapter 2 Test E-7
Not filtered	8.0x10 <sup>11</sup>						-
Filtered	8.6x10 <sup>11</sup>						-
Solids generated, gram	0.81						-
Dissipation Factor, 77° F, %							See Chapter 2 Test E-2
As-Received	2.0						See Chapter 2 Test E-5
With Sea-Water Con- tamination: (3)	2.1						-
0.5% by volume							-
2.0% by volume							-
With Carbon Contamination:							See Chapter 2 Test E-6
0.10% wt/vol.							-
0.25% wt/vol.							-
0.50% wt/vol.							-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load							-
Not filtered	0.8						-
Filtered	0.5						-
Solids generated, gram							-
Dielectric Breakdown Voltage, 0.05-inch gap, 77° F, kv							ASTM D-877 (mod- ified). See Chap- ter 2 . Test E-3
As received	23.8						See Chapter 2 Test E-5
With sea-water con- tamination: (3)	7.2						-
0.5% by volume							-
2.0% by volume							-
With carbon contamination:							See Chapter 2 Test E-6
0.10% wt/vol.							-
0.25% wt/vol.							-
0.50% wt/vol.							-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load							-
Not filtered	10.8						-
Filtered	15.8						-
Solids generated, gram							-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F							See Chapter 2 Test E-8
Number of tests							-
Operations to failure (range)							-
<u>Emulsion Stability</u>							
Paddle Test, after 1-hour set- tling:							ASTM D-1401
Oil, ml	33						-
Emulsion, ml	30						-
Water, ml	14						-
Electric Probe Test, time for water separation, min	10						See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>							See Chapter 2 Test C-3
Butyl	Poor						-
Buna N	Fair-Good						-
Viton R	Good						-
Ethylene-Propylene	Poor						-
Tetrafluoroethylene (Teflon)	Good						-
Neoprene	Fair						-
Thiokol	-						-
Silicone	Poor						-
Fluorosilicone	Poor						-

\* Based on atmospheric pressure data.

Volatility		Petroleum				Method
Toxicity			25° F	100° F	150° F	
Density, grams/cubic centimeter, at:						
0 psig	0.8659	0.8401	0.8202			
3,000 psig	0.8756	0.8516	0.8335			
5,000 psig	0.8818	0.8585	0.8414			
8,000 psig	0.8905	0.8679	0.8513			
10,000 psig	0.8957	0.8739	0.8580			
15,000 psig	0.9076	0.8867	0.8720			
20,000 psig	0.9189	0.8981	0.8839			
Isothermal Compressibility, volume decrease, %, at:						
0 psig	1.12	1.29	1.60			
3,000 psig	1.81	2.07	2.52			
5,000 psig	2.76	3.12	3.66			
8,000 psig	3.33	3.75	4.40			
10,000 psig	4.60	5.12	5.94			
15,000 psig	5.77	6.32	7.21			
Chemical Stability						
Oxidation Stability Test, 203° F, hours to failure						ASTM D-943
Oxidation Stability Test, 250° F						
Hydrolytic Stability Test						
Specimen change, mg						Fed. Method 5308
Specimen appearance						Military specification MIL-H-19457B
Fluid acid number increase, mg KOH/gram fluid						-
Water acidity, mg KOH						-
Insolubles, %						-
Thermal Stability Test						-
Fire Resistance						
Flash Point, °F	215					ASTM D-92
Fire Point, °F	250					ASTM D-92
Autogeneous Ignition Temperature, °F						ASTM D-2155
High-Pressure Spray Combustor						
Minimum spontaneous ignition temperature, °F						See MEL Report 31/66 of March 1967
Minimum reaction temperature °F						-
No indication of fire, °F						-
Maximum pressure change, psi						-
Lowest temperature of maximum pressure change, °F						-
Temperature range explored, °F						-
Miscellaneous Properties						
Pour Point, °F	<75					ASTM D-97
Foaming Tendency, 75° F						ASTM D-892
Foam after 5-minute aeration, ml	55					-
Time out, minutes	1					-
Foam after 10-minute settling, ml						-
Neutralization Number, mg KOH/gram	0.18					ASTM D-974
Water Content, % by weight	0.011					ASTM D-1744
Neutrality, qualitative	-					Fed. Method 5101
Contamination						
Number and size of particles and fibers in 100-ml fluid						
25-100 micrometers						SAE Method ARP-598
100-500 micrometers						-
over 500 micrometers						-
particles over 250 micrometers except fibers (length ten times diameter)						-
Gravimetric Value, mg/100 ml						
Color						SAE Method ARP-785
Cost, \$/gal	\$2.60					ASTM D-1500
Availability	govt spec					-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>2</sup>Heavy deposits indicate corrosion not shown by weight change. <sup>3</sup>Saturated with seawater. <sup>4</sup>Some rust observed in system.

Supplementary Properties of MIL-H-5606B

		Method
<u>Material Compatibility with:</u> Natural Rubber Buna S	Poor Poor	See Chapter II Test C-3
<u>Miscellaneous Properties</u> Specific Gravity	0.86	ASTM D-1298

\* Based on atmospheric pressure data.

Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-J-5624F is petroleum-base jet engine fuel. The JP-5 grade of the fluid has been suggested for deep ocean applications because of its low viscosity. The few relevant values known for MIL-J-5624F (JP-5) indicate it to be of questionable value for any electrical applications because of low dielectric breakdown voltage. Studies of diesel fuel as a lubricant lead to the prediction that JP-5 would have poor lubricating ability. It lacks corrosion inhibiting properties and is also highly flammable.

Properties of MIL-J-5624P, JP-5(1)  
(Petroleum Base Fluid)

				Method
				See NSRDL Annapolis Report MATLAB 350
<u>Viscometric Properties</u>				
Viscosity, centistokes, at:	35° F	100° F	150° F	
0 psig				
3,000 psig				
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
Viscosity, centistokes, at -30° F, 16.5 max				ASTM D-445
0 psig				
Viscosity Slope, ASTM				
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				Fed. Method 6503 (modified)
1 kg				
3 kg				
5 kg				
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper				
Stainless Steel, 316				
Copper-Nickel (70-30)				
Aluminum, QQ-A-250-4b				
Phosphor-Bronze				
Steel, galvanized				
Steel, 1009				
Aluminum, QQ-A-250-11				
Bronze				
Monel				
Silver Base Brazing Alloy				
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				
Stainless Steel, 316				
Copper-Nickel (70-30)				
Aluminum, QQ-A-250-4b				
Phosphor-Bronze				
Steel, galvanized				
Steel, 1009				
Aluminum, QQ-A-250-11				
Bronze				
Monel				
Silver Base Brazing Alloy				

Corrosion Protection (Cont)					
Method					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum, QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1004	-				
Aluminum, QQ-A-250-11 -	-				
Bronze	-				
Aluminum, QQ-A-250-4b -	-				
Steel, 1009	-				
20,000 PSIG Stirred Corrosion					
Test, weight change, mg	See Chapter 2 Test C-4				
Insulated Specimens:					
Copper	-				
Stainless Steel, 316	-				
Copper-Nickel (70-30)	-				
Aluminum, QQ-A-250-4b	-				
Phosphor-Bronze	-				
Steel, galvanized	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11	-				
Bronze	-				
Monel	-				
Silver Base Brazing Alloy	-				
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum, QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11 -	-				
Bronze	-				
Aluminum, QQ-A-250-4b -	-				
Steel, 1009	-				
Pump Test					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					
each, mg/cm <sup>2</sup>					
Copper	-				
Aluminum	-				
Steel, galvanized	-				
Steel, 1009	-				
Silver Base Brazing Alloy	-				
Dielectric Properties					
Resistivity, 72° F, ohm-cm:					
As-Received	4.0x10 <sup>11</sup>				
With Sea-Water Contamination:					
0.1% by volume					
0.5% by volume					
2.0% by volume					
With Carbon Contamination:					
0.1% wt/vol.					
0.25% wt/vol.					
0.5% wt/vol.					

		Method				
<u>Dielectric Properties (Cont)</u>						
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Dissipation Factor, 72° F, %						
As-Received		1.3				
With Sea-Water Contamination:						
0.1% by volume						
0.5% by volume						
2.0% by volume						
With Carbon Contamination:						
0.10% wt/vol.						
0.25% wt/vol.						
0.50% wt/vol.						
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Dielectric Breakdown Voltage, 0.05-inch gap, 72° F, kv						
As received		13.1				
With sea-water contamination:						
0.1% by volume						
0.5% by volume						
2.0% by volume						
With carbon contamination:						
0.10% wt/vol.						
0.25% wt/vol.						
0.50% wt/vol.						
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Contact Life, silver-cadmium, 10 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						
Number of tests						
Operations to failure (range)						
<u>Emulsion Stability</u>						
Paddle Test, after 1-hour set- tling:						
Oil, ml						
Emulsion, ml						
Water, ml						
Electric Probe Test, time for water separation, min						
<u>Material Compatibility Static 20KPSI</u>						
Butyl						
Buna N						
Viton B						
Ethylene-Propylene						
Tetrafluoroethylene (Teflon)						
Neoprene						
Thiokol						
Silicone						
Fluorosilicone						

				Method
				-
				-
<u>Volatility</u>				
<u>Toxicity</u>				
Density, grams/cubic centimeter, at:	Petroleum			
0 psig	35° F	100° F	150° F	
3,000 psig				See NSRDL Annapolis Report NATLAB 350
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Isothermal Compressibility, volume decrease, %, at:</u>	35° F	100° F	150° F	
0 psig				See NSRDL Annapolis Report NATLAB 350
3,000 psig				
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Chemical Stability</u>				
Oxidation Stability Test, 203° F, hours to failure				ASTM D-947
Oxidation Stability Test, 250° F				Fed. Method 530M
Hydrolytic Stability Test				Military specification MIL-H-19457B
Specimen change, mg				-
Specimen appearance				-
Fluid acid number increase, mg KOH/gram fluid				-
Water acidity, mg KOH				-
Insolubles, %				-
Thermal Stability Test				-
<u>Fire Resistance</u>				
Flash Point, °F				ASTM D-92
Fire Point, °F				ASTM D-92
Autogeneous Ignition Temperature, °F				ASTM D-7155
High-Pressure Spray Combustor				See NEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F				-
Minimum reaction temperature, °F				-
No indication of fire, °F				-
Maximum pressure change, psi				-
Lowest temperature of maximum pressure change, °F				-
Temperature range explored, °F				-
<u>Miscellaneous Properties</u>				
Pour Point, °F				ASTM D-97
Foaming Tendency, 75° F				ASTM D-892
Foam after 5-minute aeration, ml				-
Time out, minutes				-
Foam after 10-minute settling, ml				-
Neutralization Number, mg KOH/gram				ASTM D-974
Water Content, % by weight				ASTM D-1744
Neutrality, qualitative				Fed. Method 5101
Contamination				-
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP-598
25-100 micrometers				-
100-500 micrometers				-
over 500 micrometers				-
particles over 250 micrometers except fibers (length ten times diameter)				-
Gravimetric Value, mg/100 ml				SAE Method ARP-785
Specific Gravity, 60/60° F	0.79-0.85			ASTM D-1500
Color				-
Cost, \$/gal	available	from supplier		
Availability	Govt. spec			

MIL-L-6081C, Grade 1010

Suggested Uses and Possible Limitations

The fluid covered by MIL-L-6081C is a low-viscosity, petroleum-base fluid originally developed as a jet engine lubricating oil. The data given here were collected on the 1010 grade. The lubricating, electrical, and chemical properties of MIL-L-6081C indicate that it may be used as a general purpose fluid for depths down to 8000 feet. All of its properties deteriorate rapidly when it becomes contaminated with seawater. Its corrosion inhibiting properties are so poor that ball bearings in moving machinery rusted in MIL-L-6081C contaminated with seawater. Its flammability properties are marginal. While its initial dielectric properties are good, it shows a rapid drop in dielectric breakdown voltage with sea-water contamination. This makes it a questionable choice for any electrical application.

Properties of MIL-L-6081c<sup>(1)</sup>  
(Petroleum Base Fluid)

				Method
<u>Viscometric Properties</u>				
Viscosity, centistokes, at:				
0 psig	53.73	10.08	5.85	
3,000 psig	93.56	15.43	6.50	
5,000 psig	139.7	19.77	7.81	
8,000 psig	228.5	28.98	11.15	
10,000 psig	323.6	37.37	13.35	
15,000 psig	778.6	59.84	21.98	
20,000 psig	1834	129.9	36.23	
Viscosity, centistokes, at 210° F.				
0 psig	2.51			ASTM D-445
Viscosity Slope, ASTM	0.83			-
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:				Fed. Method 6965 (modified)
1 kg				-
3 kg				-
5 kg				-
15 kg	0.43	0.70		
Rolling Contact Fatigue Test, hr:				
B10 life: Dry	33.5			
With 1% synthetic seawater	15.3			
B50 life: Dry	135.4			
With 1% synthetic seawater	28.7			
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter C Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter C Test C-1
Copper	-42.6			-
Stainless Steel, 316	+ 1.0			-
Copper-Nickel (70-30)	- 0.1			-
Aluminum, QQ-A-250-4b	+185.2(2)			-
Phosphor-Bronze	-54.2			-
Steel, galvanized	-661.4			-
Steel, 1009	-74.7			-
Aluminum, QQ-A-250-11	-60.5			-
Bronze	-34.2			-
Monel	+ 0.4			-
Silver Base Braze Alloy	-5.4(2)			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter C Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Braze Alloy				-

				Method
<u>Corrosion Protection (Cont.)</u>				
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				-
Aluminum QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Brazing Alloy -				-
Steel, 1004				-
Aluminum QQ-A-250-11 -				-
Bronze				-
Aluminum QQ-A-250-4b -				-
Steel, 1009				-
20,000 PSIG Stirred Corrosion				See Chapter 2
Test, weight change, mg				Test C-4
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				-
Aluminum, QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Brazing Alloy -				-
Steel, 1009				-
Aluminum, QQ-A-250-11 -				-
Bronze				-
Aluminum, QQ-A-250-4b -				-
Steel, 1009				-
Pump Test				Proposed military specification for sea-water emulsifying oils
Average Weight Loss, mg				
Steel Gears	298			
Bronze Bushing	31			
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>				
Copper	0			-
Aluminum	0			-
Steel, galvanized	3.2			-
Steel, 1009	1.4			-
Silver Base Brazing Alloy	0.02			-
Dielectric Properties				ASTM D-1160 (modified). See Chapter 2, Test E-1
Resistivity, 70° F, ohm-cm:				See Chapter 2, Test E-2
As-Received	(3)	$6.4 \times 10^{12}$		
With Sea-Water Contamination:		$9.7 \times 10^{12}$		
1% by volume				-
2.0% by volume				-
With Carbon Contamination:				See Chapter 2, Test E-6
0.1% wt/vol.				-
0.25% wt/vol.				-
0.5% wt/vol.				-

		Method			
<u>Dielectric Properties (Cont)</u>					
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					See Chapter 2 Test E-7
Not filtered	$2.0 \times 10^{12}$				-
Filtered	$1.9 \times 10^{12}$				-
Solids generated, gram	0.70				-
Dissipation Factor, 78° F, %					See Chapter 2 Test E-2
As-Received	1.0				See Chapter 2 Test E-5
With Sea-Water Contamination <sup>(3)</sup>	3.7				-
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With Carbon Contaminations					See Chapter 2 Test E-6
0.10% wt/vol.					-
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					-
Not filtered	0.3				-
Filtered	1.0				-
Solids generated, gram					-
Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv					ASTM D-877 (modified). See Chapter 2, Test E-5
As received	20.5				See Chapter 2 Test E-5
With sea-water contamination <sup>(3)</sup>	<5.0				-
0.5% by volume					-
2.0% by volume					-
With carbon contamination:					See Chapter 2 Test E-6
0.10% wt/vol.					-
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					-
Not filtered	17.6				-
Filtered	22.8				-
Solids generated, gram					-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F					See Chapter 2 Test E-8
Number of tests					-
Operations to failure (see 1)					-
<u>Emulsion Stability</u>					
Paddle test, after 1-hour set- tling:					ASTM D-1401
Oil, ml	40				-
Emulsion, ml	-				-
Water, ml	40				-
Electric Probe Test, time for water separation, min	1.5				See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>					
Butyl	Poor				See Chapter 2 Test C-3
Buna N	Good				-
Viton B	Good				-
Ethylene-Propylene	Poor				-
Tetrafluoroethylene (Teflon)	Good				-
Neoprene	Fair				-
Toluol	-				-
Silicone	Fair				-
Fluorosilicone	Fair				-

<sup>(3)</sup>Based on atmospheric pressure data.

					Method
					-
					-
<u>Volatility</u>					
<u>Toxicity</u>					
Density, grams/cubic centimeter, at:	Petroleum	35° F	100° F	150° F	
0 psig	0.8812	0.8567	0.8380		
3,000 psig	0.8905	0.8671	0.8501		
5,000 psig	0.8959	0.8740	0.8576		
8,000 psig	0.9041	0.8831	0.8677		
10,000 psig	0.9092	0.8884	0.8738		
15,000 psig	0.9200	0.9003	0.8871		
20,000 psig	0.9304	0.9112	0.8992		
Isothermal Compressibility, volume decrease, %, at:	35° F	90° F	150° F		
0 psig	1.04	1.18	1.42		
3,000 psig	1.64	1.91	2.29		
5,000 psig	2.54	2.91	3.42		
8,000 psig	3.08	3.48	4.10		
10,000 psig	4.22	4.73	5.53		
15,000 psig	5.29	5.86	6.80		
Chemical Stability					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					
Hydrolytic Stability Test					Fed. Method 5308
Specimen change, mg					Military specification MIL-H-19457B
Specimen appearance					-
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
Fire Resistance					
Flash Point, °F	305				ASTM D-92
Fire Point, °F	335				ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combustor					See NEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
Miscellaneous Properties					
Pour Point, °F	<70				ASTM D-97
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml	45				-
Time out, minutes	1				-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram	0.05				ASTM D-974
Water Content, % by weight	0.004				ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Specific gravity at 60/60° F	0.89				ASTM-D-1298
Color					ASTM D-1500
Cost \$/gal	\$0.75				-
Availability	Gov. spec.				-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>3</sup>Saturated with seawater.

<sup>2</sup>Heavy deposits: indicates corrosion not shown by weight change. <sup>4</sup>Races and balls severely rusted. Entire oil circulating system clogged with rust.

Supplementary Properties of MIL-L-6081C(1)  
(Petroleum Base Fluid)

Material Compatibility with		Method
Brass	Poor	See Chapter II
Material Rubber	Poor	Test C-3
Polyurethane	Good	

\*Based on atmospheric pressure data.

MIL-H-6083C

Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-H-6083C is a low-viscosity, petroleum-base fluid which was developed as an aircraft and missile hydraulic system preservative. It has the same viscometric properties as MIL-H-5606B fluids, but was not intended as a working system fluid and lubricant. The properties of MIL-H-6083C indicate that it can be used for all mechanical purposes at depths to 20,000 feet with good corrosion protection and sea-water emulsifying abilities. Its lubricating ability is marginal and it is highly flammable. Low electrical resistivity and high dissipation factor make it a questionable choice for any electrical application.

Properties of MIL-H-6083c<sup>(1)</sup>  
(Petroleum Base Fluid)

				Method
<u>Viscometric Properties</u>				
Viscosity, high shear, cs, at:	35° F	100° F	150° F	
0 psig	30.25	11.78	7.27	
3,000 psig	43.35	15.66	9.24	See NSRDL
5,000 psig	55.28	18.64	10.75	Annapolis Report
8,000 psig	77.65	24.30	13.45	MATLAB 350
10,000 psig	101.6	28.59	14.02	-
15,000 psig	173.9	42.57	21.99	-
20,000 psig	311.7	63.64	30.30	-
Viscosity, low shear, cs, at:	35° F	100° F	210° F	
0 psig	49.00	15.80	9.40	
3,000 psig	74.17	21.42	11.92	
5,000 psig	92.71	26.05	14.62	
8,000 psig	136.8	33.94	18.92	
10,000 psig	175.3	39.51	22.13	
15,000 psig	325.6	61.13	33.53	
20,000 psig	591.2	93.77	48.27	
Viscosity, centistokes, at 210° F,				ASTM D-445
0 psig	4.39			-
Viscosity Slope, ASTM	0.484			
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia.,				Fed. Method 6503 (modified)
mm: 1 kg	0.12			-
3 kg	0.15			-
5 kg	0.16			-
Rolling Contact Fatigue Test, hr:				
B10 life: Dry	20.0			
With 1% synthetic seawater	14.5			
B50 life: Dry	50.6			
With 1% synthetic seawater <sup>(3)</sup>	22.0			
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Pass			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-20.5			-
Stainless Steel, 316	- 0.1			-
Copper-Nickel (70-30)	- 4.6			-
Aluminum, QQ-A-250-4b	- 1.1			-
Phosphor-Bronze	-15.4			-
Steel, galvanized	-11.4			-
Steel, 1009	+ 0.3			-
Aluminum, QQ-A-250-11	+ 0.3			-
Bronze	- 8.4			-
Monel	0			-
Silver Base Brazing Alloy	- 7.1			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper	- 6.8			-
Stainless Steel, 316	0			-
Copper-Nickel (70-30)	- 0.4			-
Aluminum, QQ-A-250-4b	- 0.1			-
Phosphor-Bronze	- 0.8			-
Steel, galvanized	- 0.1			-
Steel, 1009	- 0.2			-
Aluminum, QQ-A-250-11	- 0.1			-
Bronze	- 1.0			-
Monel	- 0.2			-
Silver Base Brazing Alloy	- 0.3			-

				Method
<b>Corrosion Protection (Cont)</b>				
<b>Electrically Coupled Specimens:</b>				
Copper-Aluminum, QQ-A-250-11	- 0.8	-0.1		-
Aluminum QQ-A-250-4b -	- 0.2	-0.5		-
Copper-Nickel (70-30)				-
Monel-Bronze	- 0.2	-0.5		-
Stainless Steel (316) -	0	-0.6		-
Phosphor-Bronze				-
Silver Base Brazing Alloy -	- 0.3	-0.1		-
Steel, 1004				-
Aluminum QQ-A-250-11 -	- 0.1	-0.8		-
Bronze				-
Aluminum QQ-A-250-4b -	- 0.1	0		-
Steel, 1009				-
<b>20,000 PSIG Stirred Corrosion Test, weight change, mg</b>	<b>(10% seawater)</b>			<b>See Chapter 2 Test C-4</b>
<b>Insulated Specimens:</b>				
Copper	- 0.1			-
Stainless Steel, 316	- 0.2			-
Copper-Nickel (70-30)	- 0.3			-
Aluminum, QQ-A-250-4b	+ 0.1			-
Phosphor-Bronze	- 0.6			-
Steel, galvanized	- 0.7			-
Steel, 1009	- 0.6			-
Aluminum, QQ-A-250-11	- 0.7			-
Bronze	- 0.4			-
Monel	- 0.6			-
Silver Base Brazing Alloy	- 0.6			-
<b>Electrically Coupled Specimens:</b>				
Copper-Aluminum, QQ-A-250-11	-0.4 -0.1			-
Aluminum, QQ-A-250-4b -	-0.2 -0.3			-
Copper-Nickel (70-30)				-
Monel-Bronze	+0.2 0			-
Stainless Steel (316) -	-0.2 -0.3			-
Phosphor-Bronze				-
Silver Base Brazing Alloy -	+0.1 -0.1			-
Steel, 1009				-
Aluminum, QQ-A-250-11 -	+0.2 +0.9			-
Bronze				-
Aluminum, QQ-A-250-4b -	+0.2 +0.8			-
Steel, 1009				-
<b>Pump Test</b>				
<b>Average Weight Loss, mg</b>				
Steel Gears	3			
Bronze Bushings	3			
<b>Corrosion Coupons, weight loss, each, mg/cm<sup>2</sup></b>				
Copper				-
Aluminum				-
Steel, galvanized				-
Steel, 1009				-
Silver Base Brazing Alloy				-
<b>Dielectric Properties</b>				
<b>Resistivity, 71° F, ohm-cm:</b>				
As-Received				ASTM D-1169 (modified). See Chapter 2, Test E-1
With Sea-Water Contamination:				See Chapter 2 Test E-5
0.1% by volume				-
0.5% by volume				-
2.0% by volume				-
With Carbon Contamination:				See Chapter 2 Test E-6
0.1% wt/vol.				-
0.25% wt/vol.				-
0.5% wt/vol.				-

								Method
<u>Dielectric Properties (Cont)</u>								
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load								See Chapter 2 Test E-7
Not filtered	2.0x10 <sup>10</sup>							-
Filtered	2.0x10 <sup>10</sup>							-
Solids generated, gram	1.00							-
Dissipation Factor, 74° F, %								See Chapter 2 Test E-2
As-Received	6.1							See Chapter 2 Test E-5
With Sea-Water Contamination:								-
0.5% by volume (2)								See Chapter 2 Test E-6
2.0% by volume (2)								-
With Carbon Contamination:								-
0.10% wt/vol.								-
0.25% wt/vol.								-
0.50% wt/vol.								-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load								-
Not filtered	10.2							-
Filtered	10.7							-
Solids generated, gram								-
Dielectric Breakdown Voltage, 0.05-inch gap, 74° F, kv								ASTM D-877 (modified). See Chapter 2, Test E-3
As received	25.5							See Chapter 2 Test E-5
With sea-water contamination:								-
0.1% by volume								-
0.5% by volume								-
2.0% by volume								-
With carbon contamination:								See Chapter 2 Test E-6
0.10% wt/vol.								-
0.25% wt/vol.								-
0.50% wt/vol.								-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load								-
Not filtered	14.0							-
Filtered	26.5							-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F								See Chapter 2 Test E-8
Number of tests	2							-
Operations to failure (range)	72-404							-
<u>Emulsion Stability</u>								ASTM D-1401
Paddle Test, after 1-hour set- tling:								-
Oil, ml	40							-
Emulsion, ml	1							-
Water, ml	39							-
Electric Probe Test, time for water separation, min	20							See Chapter 2 Test E-4
<u>Material Compatibility</u> <sup>Static 20KPSI*</sup>								See Chapter 2 Test C-3
Butyl	Poor							-
Buna N	Fair-Good							-
Viton B	Good							-
Ethylene-Propylene	Poor							-
Tetrafluoroethylene (Teflon)	Good							-
Neoprene	Fair							-
Thickol	-							-
Silicone	Poor							-
Fluorosilicone	Poor							-

\*Based on atmospheric pressure data.

Volatile Toxicity	Petroleum				Method
		35° F	100° F	150° F	
Density, grams/cubic centimeter, at:					
0 psig	0.8698	0.8445	0.8253		
3,000 psig	0.8795	0.8560	0.8388		
5,000 psig	0.8859	0.8630	0.8472		
8,000 psig	0.8948	0.8729	0.8573		
10,000 psig	0.9003	0.8786	0.8680		
15,000 psig	0.9122	0.8915	0.8773		
20,000 psig	0.9234	0.9029	0.8898		
Isothermal Compressibility, volume decrease, %, at:	35° F	90° F	150° F		
0 psig					
3,000 psig	1.10	1.29	1.62		
5,000 psig	1.82	2.08	2.48		
8,000 psig	2.79	3.17	3.74		
10,000 psig	3.39	3.79	4.93		
15,000 psig	4.65	5.15	5.93		
20,000 psig	5.81	6.33	7.24		
Chemical Stability					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					
Hydrolytic Stability Test					
Specimen change, mg					Fed. Method 5308
Specimen appearance					Military specifica-
Fluid acid number increase, mg KOH/gram fluid					cation MIL-H-19457B
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
Fire Resistance					-
Flash Point, °F	230				ASTM D-92
Fire Point, °F	235				ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combustor					See MEL Report
Minimum spontaneous ignition temperature, °F					31/66 of March
Minimum reaction temperature, °F					1967
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
Miscellaneous Properties					
Pour Point, °F	<75				ASTM D-97
Foaming Tendency, 75° F	45				ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes	1				-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-374
Water Content, % by weight	0.043				ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 microm- eters except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Specific gravity at 60/60° F	0.87				ASTM D-1298
Color	2.00				ASTM D-1300
Cost \$/gal					-
Availability	CV, ERIC				-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.  
<sup>2</sup>No rust observed.

<sup>3</sup>Saturated with seawater.

Supplementary Properties of MIL-H-6083C<sup>(1)</sup>

<u>Material Compatibility with</u> Natural Rubber Dyne S	Poor Poor	Method See Chapter 2 Test C-3
--	--------------	-------------------------------------

MIL-H-6083C fluid at 1000 psi, 230 ml of gas (measured at atmospheric pressure and 77° F) was produced by 115,000 arcs, with no arc suppression, at 50-volt open-circuit voltage and 5-ampere closed-circuit current on the contacts.

\*Based on atmospheric pressure data.

MIL-L-6085A

Suggested Uses and Possible Limitations

The fluid covered by MIL-L-6085A is a synthetic-base material usually consisting mainly of esters of dibasic organic acids. It has a low volatility and was developed for use as an aircraft instrument lubricating oil. The atmospheric pressure viscosity of MIL-L-6085A would lead to the prediction that it might be a satisfactory general-purpose fluid down to depths of 8000 feet. However, this fluid provides some limited corrosion protection. It is hydrolytically unstable. The low electrical resistivity and very high dissipation factor make its use questionable around electrical equipment. Before this oil is used in any application, the designer should consult a list of compatible materials available from the manufacturer.

Properties of MIL-L-6085A<sup>(1)</sup>  
(Synthetic Base Fluid)

				Method
Viscometric Properties	35° F	100° F	150° F	
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
5,000 psig				MATLA, 5/0
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F.	12.7			
Viscosity, centistokes, at 210° F.	3.31			ASTM D-445
0 psig				
Viscosity Slope, ASTM	0.709			-
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:				Fed. Method 6505 (modified)
1 kg				-
3 kg				-
5 kg				-
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater, 140° F, 2 days				ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 50 days				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-225.3			-
Stainless Steel, 316	0			-
Copper-Nickel (70-30)	- 2.6			-
Aluminum, QQ-A-250-4b	- 0.2			-
Phosphor-Bronze	- 47.4			-
Steel, galvanized	- 43.1			-
Steel, 1009	- 2.4			-
Aluminum, QQ-A-250-11	0			-
Bronze	- 38.0			-
Monel	- 0.2			-
Silver Base Brazing Alloy	- 48.9			-
20,000 "SIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

Method					
<u>Corrosion Protection (Cont.)</u>					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Braze Alloy -	-				
Steel, 1004	-				
Aluminum QQ-A-250-11 -	-				
Bronze	-				
Aluminum QQ-A-250-4b -	-				
Steel, 1009	-				
20,000 PSIG Stirred Corrosion					
Test, weight change, mg					
Insulated Specimens:					
Copper	-				
Stainless Steel, 316	-				
Copper-Nickel (70-30)	-				
Aluminum, QQ-A-250-4b	-				
Phosphor-Bronze	-				
Steel, galvanized	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11	-				
Bronze	-				
Monel	-				
Silver Base Braze Alloy	-				
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum, QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Braze Alloy -	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11 -	-				
Bronze	-				
Aluminum, QQ-A-250-4b -	-				
Steel, 1009	-				
Pump Test					
Average Weight Loss, mg					
Steel Gears	-				
Bronze Bushings	-				
Corrosion Coupons, weight loss,					
each, mg/cm <sup>2</sup>					
Copper	-				
Aluminum	-				
Steel, galvanized	-				
Steel, 1009	-				
Silver Base Braze Alloy	-				
Dielectric Properties					
Resistivity, 78° F, ohm-cm:					
As-Received	8.0x10 <sup>8</sup>				
With Sea-Water Contamination:					
0.1% by volume	-				
0.5% by volume	-				
2.0% by volume	-				
With Carbon Contamination:					
0.1% wt/vol.	-				
0.25% wt/vol.	-				
0.5% wt/vol.	-				
ASTM D-1169 (modified). See Chapter 2, Test E-1					
See Chapter 2, Test E-5					
See Chapter 2, Test E-6					

						Method
<u>Dielectric Properties (Cont)</u>						See Chapter 2 Test E-7
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						See Chapter 2 Test E-2
Dissipation Factor, 70° F, %						See Chapter 2 Test E-5
As-Received						-
With Sea-Water Contamination:						-
0.1% by volume						See Chapter 2 Test E-6
0.5% by volume						-
2.0% by volume						-
With Carbon Contamination:						-
0.10% wt/vol.						ASTM D-877 (mod- ified). See Chap- ter 2. Test E-3
0.25% wt/vol.						See Chapter 2 Test E-5
0.50% wt/vol.						-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						See Chapter 2 Test E-6
Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv						-
As received						-
With sea-water contamination:						See Chapter 2 Test E-5
0.1% by volume						-
0.5% by volume						See Chapter 2 Test E-6
2.0% by volume						-
With carbon contamination:						-
0.10% wt/vol.						ASTM D-1401
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						See Chapter 2 Test E-8
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						-
Number of tests						-
Operations to failure (range)						-
<u>Emulsion Stability</u>						-
Paddle Test, after 1-hour set- tling:						See Chapter 2 Test E-4
Oil, ml	8					See Chapter 2 Test C-3
Emulsion, ml	72					-
Water, ml	0					-
Electric Probe Test, time for water separation, min						-
<u>Material Compatibility</u> Static 20KPSI						-
Butyl	Poor					-
Buna N	Fair					-
Viton B	Good					-
Ethylene-Propylene	Poor					-
Tetrafluoroethylene (Teflon)	Good					-
Neoprene	Poor					-
Thiokol	-					-
Silicone	Fair					-
Fluorosilicone	Good					-

\*Based on atmospheric pressure data.

<u>Volatility</u>		<u>Synthetic</u>				<u>Method</u>
<u>Toxicity</u>			35° F	100° F	150° F	
<u>Density, grams/cubic centimeter, at:</u>	0 psig	35° F	100° F	150° F		
	3,000 psig					
	5,000 psig					
	8,000 psig					
	10,000 psig					
	15,000 psig					
	20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, at:</u>	0 psig	35° F	100° F	150° F		
	3,000 psig					
	5,000 psig					
	8,000 psig					
	10,000 psig					
	15,000 psig					
	20,000 psig					
<u>Chemical Stability</u>						
Oxidation Stability Test, 205° F, hours to failure						ASTM D-942
Oxidation Stability Test, 250° F						
Hydrolytic Stability Test						
Specimen change, mg						Fed. Method 5308
Specimen appearance						Military specification MIL-H-19457B
Fluid acid number increase, mg KOH/gram fluid						-
Water acidity, mg KOH						-
Insolubles, %						-
Thermal Stability Test						-
<u>Fire Resistance</u>						
Flash Point, °F	385					ASTM D-92
Fire Point, °F	440					ASTM D-92
Autogeneous Ignition Temperature, °F						ASTM D-2155
High-Pressure Spray Combustor						See NEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F						-
Minimum reaction temperature, °F						-
No indication of fire, °F						-
Maximum pressure change, psi						-
Lowest temperature of maximum pressure change, °F						-
Temperature range explored, °F						-
<u>Miscellaneous Properties</u>						
Pour Point, °F	<70					ASTM D-97
Foaming Tendency, 75° F						ASTM D-892
Foam after 5-minute aeration, ml						-
Time out, minutes						-
Foam after 10-minute settling, ml						-
Neutralization Number, mg KOH/gram						ASTM D-974
Water Content, % by weight						ASTM D-1744
Neutrality, qualitative						Fed. Method 51C1
Contamination						-
Number and size of particles and fibers in 100-ml fluid						SAE Method ARP-598
25-100 micrometers						-
100-500 micrometers						-
over 500 micrometers						-
particles over 250 micrometers except fibers (length ten times diameter)						-
Gravimetric Value, mg/100 ml						SAE Method ARP-785
Specific gravity at 60/60° F						ASTM D-1298
Color						ASTM D-1500
Cost \$/gal	\$10.00					-
Availability	gov. spec.					-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-L-6085A<sup>(1)</sup>

Material Compatibility with:		Method
Natural Rubber	Poor	See Chapter 2
Polyisobutene	Poor	Test C-3
Buna S	Poor	

<sup>(1)</sup>Based on atmospheric pressure data.

MIL-L-7808G

Suggested Uses and Possible Limitations

The fluid covered by MIL-L-7808G is a synthetic-base material. It was developed originally as a lubricating oil for aircraft gas turbine engines. The atmospheric viscosity indicates that MIL-L-7808G would be a general-purpose fluid with a depth capability of 5000 feet. This fluid provides some limited corrosion protection. It has poor hydrolytic stability. Caution should be used in applying this fluid to electrical equipment since its resistivity and its dissipation factor are borderline, and no data are presently available under arcing conditions. Before using this fluid the system designer should consult a list of compatible materials available from the manufacturer.

**Properties of MIL-L-7808<sup>(1)</sup>  
(Synthetic Base Fluid)**

<u>Viscometric Properties</u>		<u>35° F</u>	<u>100° F</u>	<u>150° F</u>	<u>Method</u>
Viscosity, centistokes, at:					
0 psig					See NSRDL
3,000 psig					Annapolis Report
5,000 psig					MATLAB 350
8,000 psig					-
10,000 psig					-
15,000 psig					-
20,000 psig					-
Viscosity, centistokes, at 100° F,	17.30				
Viscosity, centistokes, at 210° F,	4.50				ASTM D-445
0 psig					-
Viscosity Slope, ASTM	0.629				-
<u>Lubricating Ability</u>					
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:					Fed. Method 6503 (modified)
1 kg					-
3 kg					-
5 kg					-
<u>Corrosion Protection</u>					
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass				ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days					See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg					See Chapter 2 Test C-1
Copper	-3.3				-
Stainless Steel, 316	-0.1				-
Copper-Nickel (70-30)	-0.1				-
Aluminum, QQ-A-250-4b	-0.1				-
Phosphor-Bronze	-0.8				-
Steel, galvanized	-1.0				-
Steel, 1009	+0.1				-
Aluminum, QQ-A-250-11	-0.1				-
Bronze	-0.8				-
Monel	-2.6				-
Silver Base Brazing Alloy	-0.4				-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg					See Chapter 2 Test C-2
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Brazing Alloy					-

				Method
<u>Corrosion Protection (Cont)</u>				
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				-
Aluminum QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Braze Alloy -				-
Steel, 1004				-
Aluminum QQ-A-250-11 -				-
Bronze				-
Aluminum QQ-A-250-4b -				-
Steel, 1009				-
20,000 PSIG Stirred Corrosion				See Chapter 2
Test, weight change, mg				Test C-4
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Braze Alloy				-
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				-
Aluminum, QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Braze Alloy -				-
Steel, 1009				-
Aluminum, QQ-A-250-11 -				-
Bronze				-
Aluminum, QQ-A-250-4b -				-
Steel, 1009				-
<u>Pump Test</u>				
Average Weight Loss, mg				Proposed military specification for sea-water emulsifying oils
Steel Gears				-
Bronze Bushings				-
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>				-
Copper				-
Aluminum				-
Steel, galvanized				-
Steel, 1009				-
Silver Base Braze Alloy				-
<u>Dielectric Properties</u>				
Resistivity, 76° F, ohm-cm:	2.2x10 <sup>10</sup>			ASTM D-1169 (modified). See Chapter 2, Test E-1
As-Received				See Chapter 2
With Sea-Water Contamination:				Test E-5
0.1% by volume				-
0.5% by volume				-
2.0% by volume				-
With Carbon Contamination:				See Chapter 2
0.1% wt/vol.				Test E-6
0.25% wt/vol.				-
0.5% wt/vol.				-

		Method				
<u>Dielectric Properties (Cont)</u>		See Chapter 2 Test E-7				
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-				
Not filtered		-				
Filtered		-				
Solids generated, gram		See Chapter 2				
Dissipation Factor, 76° F, %		-				
As-Received		See Chapter 2				
With Sea-Water Contamination:		-				
0.1% by volume		Test E-2				
0.5% by volume		See Chapter 2				
2.0% by volume		-				
With Carbon Contamination:		-				
0.10% wt/vol.		See Chapter 2				
0.25% wt/vol.		-				
0.50% wt/vol.		-				
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-				
Not filtered		-				
Filtered		-				
Solids generated, gram		-				
Dielectric Breakdown Voltage, 0.05-inch gap, 76° F, kv		ASTM D-877 (modified). See Chapter 2, Test E-3				
As received		See Chapter 2				
With sea-water contamination:		-				
0.1% by volume		Test E-5				
0.5% by volume		-				
2.0% by volume		-				
With carbon contamination:		See Chapter 2				
0.10% wt/vol.		-				
0.25% wt/vol.		Test E-6				
0.50% wt/vol.		-				
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-				
Not filtered		-				
Filtered		-				
Solids generated, gram		-				
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F		See Chapter 2				
Number of tests		Test E-8				
Operations to failure (range)		-				
<u>Emulsion Stability</u>		ASTM D-1401				
Paddle Test, after 1-hour set- tling:		-				
Oil, ml		-				
Emulsion, ml		-				
Water, ml		-				
Electric Probe Test, time for water separation, min		See Chapter 2				
Material Compatibility Static 20KPSI		Test E-4				
Butyl		See Chapter 2				
Buna N		Test C-3				
Viton B		-				
Ethylene-Propylene		-				
Tetrafluoroethylene (Teflon)		-				
Neoprene		-				
Thickol		-				
Silicone		-				
Fluorosilicone		-				

\*Based on atmospheric pressure data.

		Method			
<u>Corrosion Protection (Cont.)</u>					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					
Aluminum QQ-A-250-4b -					
Copper-Nickel (70-30)					
Monel-Bronze					
Stainless Steel (316) -					
Phosphor-Bronze					
Silver Base Brazing Alloy -					
Steel, 1004					
Aluminum QQ-A-250-11 -					
Bronze					
Aluminum QQ-A-250-4b -					
Steel, 1009					
20,000 PSIG Stirred Corrosion					
Test, weight change, mg					
Insulated Specimens:					
Copper					
Stainless Steel, 316					
Copper-Nickel (70-30)					
Aluminum, QQ-A-250-4b					
Phosphor-Bronze					
Steel, galvanized					
Steel, 1009					
Aluminum, QQ-A-250-11					
Bronze					
Monel					
Silver Base Brazing Alloy					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					
Aluminum, QQ-A-250-4b -					
Copper-Nickel (70-30)					
Monel-Bronze					
Stainless Steel (316) -					
Phosphor-Bronze					
Silver Base Brazing Alloy -					
Steel, 1009					
Aluminum, QQ-A-250-11 -					
Bronze					
Aluminum, QQ-A-250-4b -					
Steel, 1009					
Pump Test					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					
Copper					
Aluminum					
Steel, galvanized					
Steel, 1009					
Silver Base Brazing Alloy					
<u>Dielectric Properties</u>					
Resistivity, 76° F, ohm-cm:	2.2×10 <sup>10</sup>				
As-Received					
With Sea-Water Contamination:					
0.1% by volume					
0.5% by volume					
2.0% by volume					
With Carbon Contamination:					
0.1% wt/vol.					
0.25% wt/vol.					
0.5% wt/vol.					

<u>Dielectric Properties (Cont.)</u>		Method				
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 2 Test E-7
Not filtered						-
Filtered						-
Solids generated, gram						-
Dissipation Factor, 76° F. %						See Chapter 2
As-Received	5.5					-
With Sea-Water Contamination:						See Chapter 2
0.1% by volume						-
0.5% by volume						Test E-2
2.0% by volume						See Chapter 2
With Carbon Contamination:						-
0.10% wt/vol.						Test E-5
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 2
Not filtered						-
Filtered						-
Solids generated, gram						-
Dielectric Breakdown Voltage, 0.05-inch gap, 76° F., kv						-
As received	25.6					ASTM D-877 (modified). See Chapter 2. Test E-3
With sea-water contamination:						See Chapter 2
0.1% by volume						-
0.5% by volume						Test E-5
2.0% by volume						-
With carbon contamination:						See Chapter 2
0.10% wt/vol.						-
0.25% wt/vol.						Test E-6
0.50% wt/vol.						-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						See Chapter 2
Number of tests						Test E-8
Operations to failure (range)						-
<u>Emulsion Stability</u>						
Paddle Test, after 1-hour settling:						ASTM D-1401
Oil, ml	2					-
Emulsion, ml	78					-
Water, ml	0					-
Electric Probe Test, time for water separation, min						See Chapter 2
<u>Material Compatibility static 20KPSI</u>						Test E-4
Butyl	Poor					See Chapter 2
Buna S	Fair					-
Viton B	Good					Test C-3
Ethylene-Propylene	Poor					-
Tetrafluoroethylene (Teflon)	Good					-
Neoprene	Poor					-
Thiokol	-					-
Silicone	Fair					-
Fluorosilicone	Good					-

\*Based on atmospheric pressure data.

					Method
		Synthetic			
<u>Volatility</u>					
<u>Toxicity</u>					
Density, grams/cubic centimeter, at:		75° F	100° F	150° F	
0 psig					See NSRDL Annapolis Report MATLAB 74
5,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
Isothermal Compressibility, volume decrease, %, at:		75° F	100° F	150° F	
0 psig					See NSRDL Annapolis Report MATLAB 74
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					
Hydrolytic Stability Test					
Specimen change, mg			0.11		
Specimen appearance			satisfac		
Fluid acid number increase, mg KOH/gram fluid			0.20		Military specification MIL-H-19407B
Water acidity, mg KOH			-		
Insolubles, %			nil		
Thermal Stability Test					
<u>Fire Resistance</u>					
Flash Point, °F		415			ASTM D-282
Fire Point, °F		445			ASTM D-282
Autogeneous Ignition Temperature, °F					ASTM D-215
High-Pressure Spray Combustor					See MEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F					
Minimum reaction temperature, °F					
No indication of fire, °F					
Maximum pressure change, psi					
Lowest temperature of maximum pressure change, °F					
Temperature range explored, °F					
<u>Miscellaneous Properties</u>					
Pour Point, °F		40			ASTM D-77
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-174
Water Content, % by weight					ASTM D-174b
Neutrality, qualitative					Fed. Method 1101
Contamination					
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-108
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-108
Specific gravity at 60.6/60° F		0.918			ASTM D-174
Color					ASTM D-174
Cost, \$/gal		\$5.00			-
Availability		gov. spec			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted

Supplementary Properties of MIL-L-7808F<sup>(1)</sup>

Material Compatibility with		Method
Natural Rubber	Poor	See Chapter 2
Polyurethane	Poor	Test C-3
Buna S	Poor	

<sup>(1)</sup>Based on atmospheric pressure data.

Suggested Uses and Possible Limitations

The fluid covered by the Military Specification MIL-L-7870A is a petroleum-base fluid developed for a low-temperature, general-purpose lubricant. The atmospheric pressure viscosity of MIL-L-7870A would lead to the prediction that it would be suitable for a general-purpose fluid for depth capability of 8000 feet. Its resistivity is low and its dissipation factor is high, making its use around electrical equipment questionable. It offers some limited corrosion protection. The low flash and fire points indicate that this fluid is readily flammable.

Properties of MIL-L-7870A<sup>(1)</sup>  
(Petroleum Base Fluid)

				Method
				See NSRDL Annapolis Report NATLAB 350
<u>Viscometric Properties</u>				
Viscosity, c centistokes, at:	35° F	100° F	150° F	
0 psig				
3,000 psig				
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
Viscosity, centistokes, at 100° F.	10.3			
Viscosity, centistokes, at 210° F.	2.52			
0 psig				
Viscosity Slope, ASTM	0.927			
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:				Fed. Method C503 (modified)
1 kg				
3 kg				
5 kg				
<u>Corrosion Protection</u>				
Stirred Fl. Test, 10% seawater, 140° F, 2 days	Pass			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-39.7			
Stainless Steel, 316	+ 0.1			
Copper-Nickel (70-30)	- 2.0			
Aluminum, QQ-A-250-4b	+ 0.2			
Phosphor-Bronze	-12.8			
Steel, galvanized	- 0.6			
Steel, 1009	- 0.4			
Aluminum, QQ-A-250-11	+ 0.4			
Bronze	- 6.6			
Monel	- 2.2			
Silver Base Brazing Alloy	-10.3			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
<u>Insulated Specimens:</u>				
Copper				
Stainless Steel, 316				
Copper-Nickel (70-30)				
Aluminum, QQ-A-250-4b				
Phosphor-Bronze				
Steel, galvanized				
Steel, 1009				
Aluminum, QQ-A-250-11				
Bronze				
Monel				
Silver Base Brazing Alloy				

					Method
<u>Corrosion Protection (Cont.)</u>					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 PSIG Stirred Corrosion					See Chapter 2
Test, weight change, mg					Test C-4
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Braze Alloy					-
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy:					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
Pump Test					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss,					
each, mg/cm <sup>2</sup>					
Copper					-
Aluminum					-
Steel, galvanized					-
Steel, 1009					-
Silver Base Braze Alloy					-
Dielectric Properties					
Resistivity, 78°F, ohm-cm:					
As-Received	7.6x10 <sup>9</sup>				ASTM D-1169 (modified). See Chapter 2, Test E-1
With Sea-Water Contamination:					See Chapter 2
0.1% by volume					Test E-5
0.5% by volume					-
2.0% by volume					-
With Carbon Contamination:					See Chapter 2
0.1% wt/vol.					Test E-6
0.25% wt/vol.					-
0.5% wt/vol.					-

Dielectric Properties (Cont.)		Method			
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram				See Chapter 2 Test E-7
Dissipation Factor, 78° F, %	14.4				-
As-Received					-
With Sea-Water Contamination:					-
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With Carbon Contamination:					See Chapter 2 Test E-2
0.10% wt/vol.					See Chapter 2 Test E-5
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram				See Chapter 2 Test E-6
Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv	30.4				-
As received					-
With sea-water contamination:					-
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With carbon contamination:					See Chapter 2 Test E-5
0.10% wt/vol.					-
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram				See Chapter 2 Test E-6
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F					-
Number of tests					-
Operations to failure (range)					-
Emulsion Stability					
Paddle Test, after 1-hour set- tling:					ASTM D-1401
Oil, ml	2				-
Emulsion, ml	78				-
Water, ml	0				-
Electric Probe Test, time for water separation, min					See Chapter 2 Test E-4
Material Compatibility Static 20KPSI*					See Chapter 2 Test C-3
Butyl	Poor				-
Buna N	Good				-
Viton B	Good				-
Ethylene-Propylene	Poor				-
Tetrafluoroethylene (Teflon)	Good				-
Neoprene	Fair				-
Thiokol	-				-
Silicone	Fair				-
Fluorosilicone	Fair				-

\*Based on atmospheric pressure data.

				Method
				-
<u>Volatility</u>				
<u>Toxicity</u>				
Density, grams/liquid centimeter, at:	Petroleum 0 psi 5,000 psi 10,000 psi 15,000 psi 20,000 psi	70° F 100° F 120° F		
100° F 150° F 200° F				See NSRDL Annapolis Report NATLAB 74
<u>Isothermal compressibility, volume decrease, %, at:</u>	70° F 100° F 120° F			
0 psi 5,000 psi 10,000 psi 15,000 psi 20,000 psi				See NSRDL Annapolis Report NATLAB 74
<u>Chemical Stability</u>				
Oxidation Stability Test, 205° F, hours to failure				ASTM D-645
Oxidation Stability Test, 250° F				
Hydrolytic Stability Test				
Specimen change, mg				Fed. Method C-108
Specimen appearance				Military Specification MIL-H-1947B
Fluid acid number increase, mg KOH/gram fluid				
Water acidity, mg KOH				
Insolubles, %				
Thermal Stability Test				
<u>Fire Resistance</u>				
Flash Point, °F	285			ASTM D-92
Fire Point, °F	310			ASTM D-92
Autogeneous Ignition Temperature, °F				ASTM D-7155
High-Pressure Spray Combustor				See NEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F				
Minimum reaction temperature, °F				
No indication of fire, °F				
Maximum pressure change, psi				
Lowest temperature of maximum pressure change, °F				
Temperature range explored, °F				
<u>Miscellaneous Properties</u>				
Pour Point, °F	~70			ASTM D-97
Foaming Tendency, 75° F				ASTM D-892
Foam after 5-minute aeration, ml				-
Time out, minutes				-
Foam after 10-minute settling, ml				-
Neutralization Number, mg KOH/gram				ASTM D-974
Water Content, % by weight				ASTM D-1744
Neutrality, qualitative				Fed. Method 9101
Contamination				-
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP-598
25-100 micrometers				-
100-500 micrometers				-
over 500 micrometers				-
particles over 250 micrometers except fibers (length ten times diameter)				-
Gravimetric Value, mg/100 ml				SAE Method ARP-785
Specific gravity at 70/60° F	0.876			ASTM D-1298
Color				ASTM D-1500
Cost \$/gal	\$1.30			-
Availability	gov. spec.			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-L-7870A(1)

<u>Material Compatibility with</u>		<u>Method</u>
Buna S	Poor	See Chapter 2
Natural Rubber	Poor	Test C-3
Polyurethane	Good	

\*Based on atmospheric pressure data.

111-66

MIL-C-8188C

Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-C-8188C is a corrosion-inhibited, synthetic-based oil which was developed as a corrosion-preventive oil for the preservation of engines which operated on MIL-L-7808 oil. It has poor hydrolytic stability. The viscosity of MIL-C-8188C leads to the prediction that it could be used at depth capability of 6000 feet. Its poor dielectric properties make it unsatisfactory for use in electrical equipment. Before using this fluid, the system designer should consult a list of compatible materials available from the manufacturer.

**Properties of MIL-C-8188C<sup>(1)</sup>**  
**(Synthetic Base Fluid)**

				Method	
		50° F	100° F	150° F	
<u>Viscometric Properties</u>					
Viscosity, centistokes, at:					
0 psig					See NERDL
3,000 psig					Aerapetrol Report
5,000 psig					MATLAB <sup>TM</sup>
8,000 psig					-
10,000 psig					-
15,000 psig					-
20,000 psig					-
Viscosity, centistokes, at 100° F.	14.14				
Viscosity, centistokes, at 210° F., 0 psig	3.90				ASTM D-441
Viscosity Slope, ASTM	0.645				
<u>Lubricating Ability</u>					
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:					Fed. Method F-97 (modified)
1 kg					-
3 kg					-
5 kg					-
Corrosion Protection					
Stirred Rust Test, 10% seawater, 140° F, 2 days					ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days					See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg					See Chapter 2 Test C-1
Copper	-27.6				-
Stainless Steel, 316	0				-
Copper-Nickel (70-30)	- 9.4				-
Aluminum, QQ-A-250-4b	+ 0.3				-
Phosphor-Bronze	-12.7				-
Steel, galvanized	- 1.7				-
Steel, 1009	0				-
Aluminum, QQ-A-250-11	+ 0.2				-
Bronze	- 8.0				-
Monel	- 1.8				-
Silver Base Brazing Alloy	- 7.7				-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg					See Chapter 2 Test C-2
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Brazing Alloy					-

				Method
Corrosion Protection (Cont)				
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				-
Aluminum, QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Brazeing Alloy				-
Steel, 1009				-
Aluminum, QQ-A-250-11 -				-
Bronze				-
Aluminum, QQ-A-250-4b -				-
Steel, 1009				-
10,000 PSIG Stirred Corrosion				See Chap 1, 2 Test C-4
Test, weight change, mg				
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazeing Alloy				-
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				-
Aluminum, QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Brazeing Alloy				-
Steel, 1009				-
Aluminum, QQ-A-250-11 -				-
Bronze				-
Aluminum, QQ-A-250-4b -				-
Steel, 1009				-
Pump Test				
Average Weight Loss, mg				
Steel Gears				
Bronze Bushings				
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>				
Copper				-
Aluminum				-
Steel, galvanized				-
Steel, 1009				-
Silver Base Brazeing Alloy				-
Dielectric Properties				
Resistivity, 78° F, ohm-cm:				
As-Received	7.8x10 <sup>8</sup>			
With Sea-Water Contamination:				
0.1% by volume				
0.5% by volume				
2.0% by volume				
With Carbon Contamination:				
0.1% wt/vol.				
0.25% wt/vol.				
0.5% wt/vol.				

Proposed military  
specification for  
sea-water emulsi-  
fying oils

ASTM D-1169 (mod-  
ified). See Chap-  
ter 2. Test E-1

See Chapter 2  
Test E-5

See Chapter 2  
Test E-6

						Method	
<u>Dielectric Properties (Cont.)</u>							
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 2 Test E-7	
Not filtered						-	
Filtered						-	
Solids generated, gram						See Chapter 2 Test E-2	
Dissipation Factor, 78° F. %	>60					See Chapter 2 Test E-5	
As-Received						-	
With Sea-Water Contamination:						See Chapter 2 Test E-6	
0.1% by volume						-	
0.5% by volume						-	
2.0% by volume						-	
With Carbon Contamination:						ASTM D-577 (modified). See Chapter 2. Test E-3	
0.10% wt/vol.						See Chapter 2 Test E-5	
0.25% wt/vol.						-	
0.50% wt/vol.						-	
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 2 Test E-6	
Not filtered						-	
Filtered						-	
Solids generated, gram						-	
Dielectric Breakdown Voltage, 0.05-inch gap, 78° F., kv	25.2					-	
As received						ASTM D-1401	
With sea-water contamination:						-	
0.1% by volume						-	
0.5% by volume						-	
2.0% by volume						-	
With carbon contamination:						See Chapter 2 Test E-8	
0.10% wt/vol.						-	
0.25% wt/vol.						-	
0.50% wt/vol.						-	
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 2 Test E-4	
Not filtered						See Chapter 2 Test C-3	
Filtered						-	
Solids generated, gram						-	
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						-	
Number of tests						-	
Operations to failure (range)						-	
<u>Emulsion Stability</u>							
Paddle Test, after 1-hour set- tling:							
Oil, ml	40						
Emulsion, ml	0						
Water, ml	40						
Electric Probe Test, time for water separation, min							
<u>Material Compatibility Static 20KPSI</u>							
Butyl	Poor						
Buna N	Fair						
Viton B	Good						
Ethylene-Propylene	Poor						
Tetrafluoroethylene (Teflon)	Good						
Neoprene	Poor						
Thiokol	-						
Silicone	Fair						
Fluorosilicone	Good						

\*Based on atmospheric pressure data.

				Method
Volatile		Synthetic		
Toxicity				
Density, grams/cubic centimeter, atm		50° F	100° F	150° F
0 psig				
5,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
Isothermal Compressibility, volume decrease, %, atm		50° F	100° F	150° F
0 psig				
5,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
Chemical Stability				
Oxidation Stability Test, 203° F, hours to failure				ASTM D-947
Oxidation Stability Test, 250° F				
Hydrolytic Stability Test				
Specimen change, mg				Fed. Method 5709
Specimen appearance				Military specification MIL-H-4477B
Fluid acid number increase, mg KOH/gram fluid				-
Water solubility, mg KOH				-
Insolubles, %				-
Thermal Stability Test				-
Fire Resistance				
Flash Point, °F		455		ASTM D-97
Fire Point, °F		500		ASTM D-97
Autogeneous Ignition Temperature, °F				ASTM D-2155
High-Pressure Spray Combustor				See NLL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F				-
Minimum reaction temperature, °F				-
No indication of fire, °F				-
Maximum pressure change, psi				-
Lowest temperature or maximum pressure change, °F				-
Temperature range explored, °F				-
Miscellaneous Properties				
Pour Point, °F		<75		ASTM D-97
Foaming Tendency, 75° F				ASTM D-97
Foam after 5-minute aeration, ml				-
Time out, minutes				-
Foam after 10-minute settling, ml				-
Neutralization Number, mg KOH/gram				ASTM D-974
Water Content, % by weight				ASTM D-1744
Neutrality, qualitative				Fed. Method 5101
Contamination				-
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP-598
25-100 micrometers				-
100-500 micrometers				-
over 500 micrometers				-
particles over 250 micrometers except fibers (length ten times diameter)				-
Gravimetric Value, mg/100 ml				SAE Method ARP-785
Specific gravity at 60/60°F	0.938			ASTM D-1298
Color				ASTM D-1500
Cost \$/gal	\$5.30			-
Availability	gov. spec.			-

Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-C-8188C(1)

<u>Material Compatibility with</u>	<u>Poor</u>	<u>Method</u>
		<u>See Chapter 2</u>
<u>Natural Rubber</u>	<u>Poor</u>	
<u>Polyurethane</u>	<u>Poor</u>	
<u>Buna S</u>	<u>Poor</u>	

\*Based on atmospheric pressure data.

Suggested Uses and Possible Limitations

The fluid covered by Military Specification MIL-F-17111 is a petroleum-base fluid which was developed as a hydraulic fluid for ordnance hydraulic systems. The viscosity at atmospheric pressure of MIL-F-17111 leads to the prediction that this fluid would be a satisfactory general-purpose fluid to depth capability of 5000 feet only. It provides some degree of corrosion protection and it is highly flammable. Initial dielectric properties are good, but additional information relating to its electrical application is lacking.

Properties of MIL-F-17111<sup>(1)</sup>  
(Petroleum Base Fluid)

Viscometric Properties	55° F	100° F	150° F	Method
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
5,000 psig				MATLAB 550
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				
Viscosity, centistokes, at 100° F	28.8			
Viscosity, centistokes, at 210° F,	10.14			ASTM D-446
0 psig				-
Viscosity Slope, ASTM	0.391			
Lubricating Ability				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				Fed. Method 650 <sup>2</sup> (modified)
1 kg				-
3 kg				-
5 kg				-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	pass			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	pass			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	+0.1			-
Stainless Steel, 316	0			-
Copper-Nickel (70-30)	0			-
Aluminum, QQ-A-250-4b	0			-
Phosphor-Bronze	+0.2			-
Steel, galvanized	-0.9			-
Steel, 1009	-0.4			-
Aluminum, QQ-A-250-11	+1.5			-
Bronze	0			-
Monel	-0.2			-
Silver Base Braze Alloy	-0.4			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Braze Alloy				

				Method	
Corrosion Protection (cont)					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-4b				-	
Aluminum, QQ-A-250-4b				-	
Copper-Nickel (70-30)				-	
Monel-Bronze				-	
Stainless Steel (316) -				-	
Phosphor-Bronze				-	
Silver Base Braze Alloy -				-	
Steel, 1009				-	
Aluminum, QQ-A-250-4b				-	
Bronze				-	
Aluminum, QQ-A-250-4b				-	
Steel, 1009				-	
70,000 PSI Stirred Corrosion Test, weight change, mg	(10% seawater)				See Chapter 2 Test C-4
Insulated Specimens:					
Copper	0			-	
Stainless Steel, 316	+0.1			-	
Copper-Nickel (70-30)	+0.3			-	
Aluminum, QQ-A-250-4b	+0.1			-	
Phosphor-Bronze	0			-	
Steel, galvanized	+0.3			-	
Steel, 1009	+0.2			-	
Aluminum, QQ-A-250-4b	+0.1			-	
Bronze	+0.4			-	
Monel	+0.1			-	
Silver Base Braze Alloy	-0.3			-	
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-4b	+0.1-0.1			-	
Aluminum, QQ-A-250-4b	-0.1-0.1			-	
Copper-Nickel (70-30)				-	
Monel-Bronze	-0.1-0.2			-	
Stainless Steel (316) -	+0.1-0			-	
Phosphor-Bronze				-	
Silver Base Braze Alloy -	+0.1-0.2			-	
Steel, 1009				-	
Aluminum, QQ-A-250-4b	0 +0.3			-	
Bronze				-	
Aluminum, QQ-A-250-4b				-	
Steel, 1009	-0.1 0			-	
Pump Test					
Average Weight Loss, mg					
Steel Gears	6				
Bronze Bushings	25				
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>	-				
Copper	0.01			-	
Aluminum	0.03			-	
Steel, galvanized	0.25			-	
Steel, 1009	0.05			-	
Silver Base Braze Alloy	0.03			-	
Dielectric Properties					
Resistivity, 77° F, ohm-cm:	8.2x10 <sup>11</sup>				
As-Received					
With Sea-Water Contamination:					
0.1% by volume					ASTM D-1159 (modified). See Chapter 2, Test E-1
0.5% by volume					Chapter 2
2.0% by volume					Test E-5
With Carbon Contamination:					-
0.1% wt/vol.					-
0.25% wt/vol.					Chapter 2
0.5% wt/vol.					Test E-6

						Method See Chapter 2 Test E-7
<u>Dielectric Properties (Cont)</u>						
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						See Chapter 2 Test E-2
Dissipation Factor, 77° F, %						See Chapter 2 Test E-5
As-Received	1.9					-
With Sea-Water Contamination:						See Chapter 2 Test E-6
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With Carbon Contamination:						See Chapter 2 Test E-5
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						-
Dielectric Breakdown Voltage, 0.05-inch gap, 77° F, kv						ASTM D-877 (modified). See Chapter 2. Test E-3
As received	23.2					See Chapter 2 Test E-5
With sea-water contamination:						-
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With carbon contamination:						See Chapter 2 Test E-6
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						See Chapter 2 Test E-8
Number of tests						-
Operations to failure (range)						-
<u>Emulsion Stability</u>						
Paddle Test, after 1-hour set- tling:						ASTM D-1401
Oil, ml	1					-
Emulsion, ml	79					-
Water, ml	0					-
Electric Probe Test, time for water separation, min.						See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>						See Chapter 2 Test C-3
Butyl	Poor					-
Duna N	Fair-good					-
Viton B	Good					-
Ethylene-Propylene	Poor					-
Tetrafluoroethylene (Teflon)	Good					-
Neoprene	Fair					-
Thiokol	-					-
Silicone	Poor					-
Fluorosilicone	Poor					-

\*Based on atmospheric pressure data.

<u>Toxicity</u>		<u>Petroleum</u>			<u>Method</u>
<u>Density, grams/cubic centimeter, atm</u>		<u>35° F</u>	<u>100° F</u>	<u>150° F</u>	
0 psig					See NSRDL Annapolis Report MATLAB 350
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, atm</u>		<u>35° F</u>	<u>100° F</u>	<u>150° F</u>	
0 psig					See NSRDL Annapolis Report MATLAB 350
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					Fed. Method 5308
Hydrolytic Stability Test					Military specification MIL-H-19457B
Specimen change, mg					-
Specimen appearance					-
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
<u>Thermal Stability Test</u>					
<u>Fire Resistance</u>					
Flash Point, °F		>220			ASTM D-92
Fire Point, °F		>235			ASTM D-52
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combustor					See NEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Pour Point, °F		<40			ASTM D-97
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-974
Water Content, % by weight		0.010			ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Specific gravity, 60/60° F		0.856			-
Color					ASTM D-1500
Cost \$/gal		\$5.00			-
Availability		gov. spec.			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-F-17111<sup>(1)</sup>

Material Compatibility with:		Method
Buna S	Poor	See Chapter 2
Natural Rubber	Poor	Test C-3

<sup>(1)</sup>Based on atmospheric pressure data.

Suggested Uses and Possible Limitations

The fluids covered by MIL-L-17672 are petroleum-base fluids which are intended for use as hydraulic fluids and light steam turbine lubricants. The fluid described here is Military Symbol (MS) 2110-TH. Although MIL-L-17672, MS 2110-TH, is used in present-day submarines, its high viscosity eliminates its use in most deep ocean applications.

**Properties of MIL-L-17672B, MS2110TH<sup>(1)</sup>  
(Petroleum Base Fluid)**

				Method	
<b>Viscometric Properties</b>					
Viscosity, centistokes, at:	35° F	100° F	140° F		
0 psig	338.1	35.68	12.69		
3,000 psig	628.4	59.23	18.71	See NSRDL	
5,000 psig	984.4	79.88	24.40	Annapolis Report	
7,000 psig	1776	125.4	35.15	MATLAB 350	
10,000 psig	2626 <sup>(2)</sup>	167.0	44.76	-	
15,000 psig	6300 <sup>(2)</sup>	334.1	80.04	-	
20,000 psig	17,400 <sup>(2)</sup>	660.8	140.9	-	
Viscosity, centistokes, at 210° F,	5.35			ASTM D-445	
0 psig				-	
Viscosity Slope, ASTM	0.771				
<b>Lubricating Ability</b>			1%		
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:	Dry	Dry	Seawater	1% Seawater	Fed. Method 6505 (modified)
5 kg	Dry argon	Dry Oxygen	Wet Argon	Wet Oxygen	-
10 kg	0.17	-	0.31	-	-
20 kg	0.24	-	0.38	0.60	-
30 kg	0.27	0.57	0.41	0.64	-
	0.72	0.62	0.65	0.70	-
<b>Corrosion Protection</b>					
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass				ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg					See Chapter 2 Test C-1
Copper	-2.7				-
Stainless Steel, 316	-0.7				-
Copper-Nickel (70-30)	-1.7				-
Aluminum, QQ-A-250-4b	+0.1				-
Phosphor-Bronze	-2.1				-
Steel, galvanized	-6.5				-
Steel, 1009	0				-
Aluminum, QQ-A-250-11	-0.1				-
Bronze	-2.0				-
Monel	-0.3				-
Silver Base Brazing Alloy	-2.1				-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg					See Chapter 2 Test C-2
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Brazing Alloy					-

Corrosion Protection (Cont.)		Method				
Electrically Coupled Specimens:						
Copper-Aluminum, QQ-A-210-11						-
Aluminum QQ-A-210-4b -						-
Copper-Nickel (70-30)						-
Monel-Bronze						-
Stainless Steel (316) -						-
Phosphor-Bronze						-
Silver Base Brazing Alloy -						-
Steel, 1009						-
Aluminum QQ-A-250-11 -						-
Bronze						-
Aluminum QQ-A-250-4b -						-
Steel, 1009						-
20,000 PSIG Stirred Corrosion						See Chapter 2 Test C-4
Test, weight change, mg						
Insulated Specimens:						
Copper						-
Stainless Steel, 316						-
Copper-Nickel (70-30)						-
Aluminum, QQ-A-250-4b						-
Phosphor-Bronze						-
Steel, galvanized						-
Steel, 1009						-
Aluminum, QQ-A-250-11						-
Bronze						-
Monel						-
Silver Base Brazing Alloy						-
Electrically Coupled Specimens:						
Copper-Aluminum, QQ-A-210-11						-
Aluminum, QQ-A-250-4b -						-
Copper-Nickel (70-30)						-
Monel-Bronze						-
Stainless Steel (316) -						-
Phosphor-Bronze						-
Silver Base Brazing Alloy -						-
Steel, 1009						-
Aluminum, QQ-A-250-11 -						-
Bronze						-
Aluminum, QQ-A-250-4b -						-
Steel, 1009						-
Pump Test						Proposed test for specification for sea-water emulsi- fying oils
Average Weight Loss, mg						
Steel Gears	138					
Bronze Bushings	480					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>						
Copper	0.01					-
Aluminum	0.05					-
Steel, galvanized	0.01					-
Steel, 1009	0.04					-
Silver Base Brazing Alloy	0.02					-
Dielectric Properties						
Resistivity, 72° F, ohm-cm:						ASTM D-1169 (mod- ified). See Chap- ter 2, Test E-1
As-Received	4.4x10 <sup>12</sup>					Chapter 2 Test E-5
With Sea-Water Contamination:						-
0.1% by volume	5.4x10 <sup>11</sup>					-
0.5% by volume						Chapter 2 Test E-6
2.0% by volume						-
With Carbon Contamination: <sup>(3)</sup>						-
0.1% wt/vol.						-
0.25% wt/vol.						-
0.5% wt/vol.						-

				Method
<u>Dielectric Properties (Cont.)</u>				
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				See Chapter 2 Test E-7
Not filtered	8.6x10 <sup>11</sup>			-
Filtered	4.2x10 <sup>11</sup>			-
Solids generated, gram	1.33			-
Dissipation Factor, 72° F, %				See Chapter 2 Test E-2
As-Received	1.0			See Chapter 2 - Test E-5
With Sea-Water Contamination:	0.9			-
0.1% by volume				-
0.5% by volume				-
2.0% by volume				-
With Carbon Contamination:				See Chapter 2 Test E-6
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered	1.6			-
Filtered	1.2			-
Dielectric Breakdown Voltage, 0.05-inch gap, 72° F, kv				ASTM D-877 (modified). See Chapter 2. Test E-5
As received	15.3			See Chapter 2 Test E-5
With sea-water contamination <sup>(3)</sup>	5.5			-
0.5% by volume				-
2.0% by volume				-
With carbon contamination:				See Chapter 2 Test E-6
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered	10.7			-
Filtered	22.1			-
Solids generated, gram				-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				See Chapter 2 Test E-3
Number of tests				-
Operations to failure (range)				-
<u>Emulsion Stability</u>				ASTM D-1401
Paddle Test, after 1-hour settling:				
Oil, ml	40			-
Emulsion, ml	0			-
Water, ml	40			-
Electric Probe Test, time for water separation, min	18			See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>				See Chapter 2 Test C-3
Butyl	Poor			-
Buna N	Good			-
Viton B	Good			-
Ethylene-Propylene	Poor			-
Tetrafluoroethylene (Teflon)	Good			-
Neoprene	Fair			-
Thickol	-			-
Silicone	Fair			-
Fluorosilicone	Fair			-

\*Based on atmospheric pressure data.

Volatile		Petroleum			Method
<u>Toxicity</u>					-
Density, grams/cubic centimeter, at:	35° F	100° F	150° F		
0 psig	0.8666	0.8652	0.8468		
5,000 psig	0.8958	0.8735	0.8588		
5,000 psig	0.9014	0.8796	0.8656		
8,000 psig	0.9092	0.8879	0.8747		
10,000 psig	0.9140	0.8933	0.8805		
15,000 psig	0.9213	0.9050	0.8928		
20,000 psig	0.9347	0.9157	0.9041		
<u>Isothermal Compressibility, volume decrease, %, at:</u>		35° F	100° F	150° F	
0 psig					
5,000 psig	1.03	1.14	1.40		
5,000 psig	1.64	1.80	2.17		
8,000 psig	2.48	2.73	3.19		
10,000 psig	3.00	3.29	3.83		
15,000 psig	4.11	4.53	5.15		
20,000 psig	5.15	5.62	6.34		
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure	1000+				ASTM D-943
Oxidation Stability Test, 250° F					Fed. Method 5308
Hydrolytic Stability Test					Military specification MIL-H-19457B
Specimen change, mg					-
Specimen appearance					-
luid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
<u>Thermal Stability Test</u>					-
<u>Fire Resistance</u>					
Flash Point, °F	360				ASTM D-92
Fire Point, °F	385				ASTM D-92
Autogeneous Ignition Temperature, °F	690				ASTM D-2155
High-Pressure Spray Combustor					See NEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F	453				-
Minimum reaction temperature, °F	425				-
No indication of fire, °F	425				-
Maximum pressure change, psi	325				-
Lowest temperature of maximum pressure change, °F	453				-
Temperature range explored, °F	425-479				-
<u>Miscellaneous Properties</u>					
Pour Point, °F	-15				ASTM D-97
Foaming Tendency, 75° F	40				ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes	1				-
Foam after 10-minute settling, ml	0				-
Neutralization Number, mg KOH/gram	0.02				ASTM D-974
Water Content, % by weight	0.015				ASTM D-1744
Neutrality, qualitative	Neutral				Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Specific gravity at 60/60° F	0.88				-
Color	1.5				ASTM D-1500
Cost \$/gal	\$0.60				-
Availability	gov. spec.				-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>2</sup>Extrapolated value. <sup>3</sup>Saturated with seawater.

Supplementary of Properties of MIL-L-17672B, MS 2110H<sup>(1)</sup>  
(Petroleum Base Fluid)

<u>Material Compatibility with:</u>		<u>Method</u>
Buna S	Poor	See Chapter 2
Natural Rubber	Poor	Test C-5
Polyurethane	Good	

\*Based on atmospheric pressure data.

MIL-S-21568A

Suggested Uses and Possible Limitations

The fluid covered by MIL-S-21568A is a 1-cs viscosity dimethyl polysiloxane fluid. MIL-S-21568A has been superseded by Federal Specification VV-D-001078. Since there is no 1-cs viscosity fluid covered by VV-D-001078, the older specification which contains such a fluid had to be used. MIL-S-21568A (1 cs) is considered unsatisfactory for use with motors because of its very low viscosity and poor sea-water emulsion stability. Because of its good dielectric properties, as well as low viscosity, it is the best choice known to date for switching devices and other nonmoving electrical applications.

Properties of MIL-S-21568A(1 CS)<sup>(1)</sup>

(Silicone Base Fluid)

Viscometric Properties	35° F	100° F	150° F	Method
Viscosity, centistokes, at:				
0 psig	1.19	0.76	0.44	
3,000 psig	2.19	0.96	0.68	See NSRDL Annapolis Report
6,000 psig	2.95	1.25	0.83	MATLAB 5.0
8,000 psig	4.29	1.73	1.19	-
10,000 psig	5.11	1.97	1.31	-
14,000 psig	8.12	2.91	1.77	-
20,000 psig	11.56	3.92	2.46	-
Viscosity, centistokes, at 210° F,	-	-	-	ASTM D-446
0 psig	-	-	-	-
Viscosity Slope, ASTM	0.854	-	-	-
Lubricating Ability	Dry	+ 1% Synthetic Seawater		Fed. Method 6105 (modified)
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				
1 kg	0.65	-		-
3 kg	1.02	-		-
5 kg	0.63	0.39		-
15 kg	0.70	0.50		-
30 min, 50° C, 52100 steel				
60 min, 10° C, 52100 steel				
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-			-
Stainless Steel, 316	-			-
Copper-Nickel (70-30)	-			-
Aluminum, QQ-A-250-4b	-			-
Phosphor-Bronze	-			-
Steel, galvanized	-			-
Steel, 1009	-			-
Aluminum, QQ-A-250-11	-			-
Bronze	-			-
Monel	-			-
Silver Base Braze Alloy	-			-
20,000 PSIC Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper	-			-
Stainless Steel, 316	-			-
Copper-Nickel (70-30)	-			-
Aluminum, QQ-A-250-4b	-			-
Phosphor-Bronze	-			-
Steel, galvanized	-			-
Steel, 1009	-			-
Aluminum, QQ-A-250-11	-			-
Bronze	-			-
Monel	-			-
Silver Base Braze Alloy	-			-

		Method	
<u>Corrosion Protection (Cont)</u>			
Electrically Coupled Specimens:			
Copper-Aluminum, QQ-A-210-11	-		
Aluminum QQ-A-210-4b -	-		
Copper-Nickel (70-30)	-		
Monel-Bronze	-		
Stainless Steel (316) -	-		
Phosphor-Bronze	-		
Silver Base Brazing Alloy -	-		
Steel, 1009	-		
Aluminum QQ-A-250-11 -	-		
Bronze	-		
Aluminum QQ-A-250-4b -	-		
Steel, 1009	-		
10,000 PSIG Stirred Corrosion			See Chapter 1
Test, weight change, mg			Test C-4
Insulated Specimens:			
Copper	-		
Stainless Steel, 316	-		
Copper-Nickel (70-30)	-		
Aluminum, QQ-A-250-4b	-		
Phosphor-Bronze	-		
Steel, galvanized	-		
Steel, 1009	-		
Aluminum, QQ-A-250-11	-		
Bronze	-		
Monel	-		
Silver Base Brazing Alloy	-		
Electrically Coupled Specimens:			
Copper-Aluminum, QQ-A-210-11	-		
Aluminum, QQ-A-250-4b -	-		
Copper-Nickel (70-30)	-		
Monel-Bronze	-		
Stainless Steel (316) -	-		
Phosphor-Bronze	-		
Silver Base Brazing Alloy -	-		
Steel, 1009	-		
Aluminum, QQ-A-250-11 -	-		
Bronze	-		
Aluminum, QQ-A-250-4b -	-		
Steel, 1009	-		
Pump Test			Proposed military specification for sea-water emulsifying oils
Average Weight Loss, mg			
Steel Gears	-		
Bronze Bushings	-		
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>			
Copper	-		
Aluminum	-		
Steel, galvanized	-		
Steel, 1009	-		
Silver Base Brazing Alloy	-		
Dielectric Properties			
Resistivity, 70° F, ohm-cm:			ASTM D-116 (modified). See Chapter 2. Test E-1
As-Received	2.2x10 <sup>13</sup>		Chapter 2
With Sea-Water Contamination:	2.4x10 <sup>13</sup>		Test E-5
0.5% by volume	-		
2.0% by volume	-		
With Carbon Contamination:			Chapter 2
0.1% wt/vol.			Test E-6
0.25% wt/vol.			
0.5% wt/vol.			

		Method			
<u>Dielectric Properties (Cont)</u>		See Chapter 2 Test E-7			
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-			
Not filtered		-			
Filtered		-			
Solids generated, gram		See Chapter 2 Test E-2			
Dissipation Factor, 78° F, %		See Chapter 2 Test E-5			
As-Received (2)		-			
With Sea-Water Contamination:		-			
0.5% by volume		See Chapter 2 Test E-6			
2.0% by volume		-			
With Carbon Contamination:		-			
0.10% wt/vol.		-			
0.25% wt/vol.		-			
0.50% wt/vol.		-			
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		ASTM D-877 (modified). See Chapter 2. Test E-3			
Not filtered		See Chapter 2 Test E-5			
Filtered		-			
Solids generated, gram		-			
Dielectric Breakdown Voltage, 0.05-inch gap, 78° F, kv		See Chapter 2 Test E-6			
As received (2)		-			
With sea-water contamination:		-			
0.5% by volume		-			
2.0% by volume		-			
With carbon contamination:		-			
0.10% wt/vol.		-			
0.25% wt/vol.		-			
0.50% wt/vol.		-			
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-			
Not filtered		-			
Filtered		-			
Solids generated, gram		-			
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F		See Chapter 2 Test E-8			
Number of tests		-			
Operations to failure (range)		-			
<u>Emulsion Stability</u>		ASTM D-1401			
Paddle Test, after 1-hour set- tling:		-			
Oil, ml		-			
Emulsion, ml		-			
Water, ml		-			
Electric Probe Test, time for water separation, min		See Chapter 2 Test E-4			
<u>Material Compatibility Static 20K PSI</u>		See Chapter 2 Test C-3			
Butyl		-			
Buna N		-			
Viton B		-			
Ethylene-Propylene		-			
Tetrafluoroethylene (Teflon)		-			
Neoprene		-			
Thiokol		-			
Silicone		-			
Fluorosilicone		-			

Physical Properties		Silicone			See NSPDL	
Density, g./cubic centimeter, at:	50° F	100° F	140° F		Author: Dr. R. E. P. T.	
0 psig	0.8353	0.8069	0.7709		MATERIAL: 00	
1,000 psig	0.8943	0.8189	0.7916			
2,000 psig	0.8659	0.8799	0.8656			
3,000 psig	0.8769	0.8455	0.8177			
4,000 psig	0.8844	0.8516	0.8267			
5,000 psig	0.9012	0.8687	0.8447			
6,000 psig	0.9161	0.8840	0.8614			
Isothermal compressibility, volume decrease, %, at:	50° F	90° F	140° F		Author: Dr. R. E. P. T.	
0 psig					MATERIAL: 00	
1,000 psig	2.21	2.75	3.65			
2,000 psig	3.55	4.21	5.38			
3,000 psig	5.19	6.11	7.56			
4,000 psig	5.61	7.17	8.77			
5,000 psig	8.70	9.41	11.87			
6,000 psig	3.85	10.95	13.00			
Chemical Stability					ASTM D-6	
Oxidation Stability Test, 20° F, hours to failure					Fed. Method 70	
Oxidation Stability Test, 100° F					Military: pt. 1 -	
Hydrolytic Stability Test					pt. 2 - MIL-H-1	
Specimen changes, mg					1000	
Color, $\Delta E$ , appearance					-	
Fluid acid number increase, mg KOH/gram fluid					-	
Water acidity, mg KOH					-	
Insolubles, %					-	
Thermal Stability Test					-	
Fire Resistance					-	
Flash Point, °F	115				ASTM D-92	
Fire Point, °F	115				ASTM D-93	
Auto-ignition Temperature, °F					ASTM D-2155	
High-Pressure Spray Combustor					See MIL Report	
Minimum spontaneous ignition temperature, °F					41/66 of March	
Minimum reaction temperature, °F					1977	
No indication of fire, °F					-	
Maximum pressure change, psi					-	
Lowest temperature of maximum pressure change, °F					-	
Temperature range explored, °F					-	
Miscellaneous Properties						
Pour Point, °F	<70				ASTM D-97	
Foaming Tendency, 75° F					ASTM D-892	
Foam after 5-minute aeration, ml	0				-	
Time out, minutes					-	
Foam after 10-minute settling, ml					-	
Neutralization Number, mg KOH/gram					ASTM D-274	
Water Content, % by weight	0.026				ASTM D-1744	
Neutrality, qualitative					Fed. Method 10C	
Contamination					-	
Number and size of particles and fibers in 100-ml fluid					SAE Method FED-598	
25-100 micrometers					-	
100-200 micrometers					-	
over 200 micrometers					-	
particles over 250 micrometers except fibers (length ten times diameter)					-	
Gravimetric Value, mg/100 ml	0.800				SAE Method ARP-78	
Specific gravity at 60/60° F						
Color					ASTM D-1101	
Cost, \$/gal	\$35.00				-	
Availability	gov. spec.				-	

<sup>1</sup> Determinations made at atmospheric pressure, unless noted. Saturated with seawater.

Suggested Uses and Possible Limitations

The fluid described in Military Specification MIL-L-23699A is a synthetic-base lubricant which was developed for aircraft turboprop and turboshaft engines. The atmospheric pressure viscosity of MIL-L-23699A leads to the prediction that it would be too viscous for most deep ocean applications. It has poor hydrolytic stability. It does provide some limited corrosion protection. Dielectric properties have not been determined. Before using this fluid, a system designer should consult a list of compatible materials available from the manufacturer.

**Properties of MIL-L-25699A<sup>(1)</sup>  
(Synthetic Base Fluid)**

				Method
Viscometric Properties	35° F	100° F	110° F	
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
5,000 psig				MATLAB 5.0
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F,	25.67			
Viscosity, centistokes, at 210° F,	5.00			ASTM D-445
0 psig				-
Viscosity Slope, ASTM	0.702			-
Lubricating Ability				E. d. Method C-5 (modified)
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				-
1 kg				-
3 kg				-
5 kg				-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-0.2			-
Stainless Steel, 316	+0.1			-
Copper-Nickel (70-30)	-0.2			-
Aluminum, QQ-A-250-4b	+0.5			-
Phosphor-Bronze	-0.3			-
Steel, galvanized	-1.5			-
Steel, 1009	-186.2			-
Aluminum, QQ-A-250-11	+0.2			-
Bronze	-0.2			-
Monel	-0.1			-
Silver Base Brazing Alloy	-0.2			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

					Method
<u>Corrosion Protection (Cont)</u>					
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 PSIG Stirred Corrosion					See Chapter 2
Test, weight change, mg					Test C-4
<u>Insulated Specimens:</u>					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Braze Alloy					-
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
<u>Pump Test</u>					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss,					
each, mg/cm <sup>2</sup>					
Copper					-
Aluminum					-
Steel, galvanized					-
Steel, 1009					-
Silver Base Braze Alloy					-
<u>Dielectric Properties</u>					
Resistivity, F, ohm-cm:					ASTM D-1169 (modified). See Chapter 2. Test E-1
As-Received					Chapter 2
With Sea-Water Contamination:					Test E-5
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With Carbon Contamination:					Chapter 2
0.1% wt/vol.					Test E-6
0.25% wt/vol.					-
0.5% wt/vol.					-

				Method	
<u>Dielectric Properties (Cont.)</u>					
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					See Chapter 2 Test E-7
Not filtered					-
Filtered					-
Solids generated, gram					-
Dissipation Factor, °F, %					See Chapter 2
As-Received					- Test E-2
With Sea-Water Contamination:					See Chapter 2 Test E-5
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With Carbon Contamination:					See Chapter 2 Test E-6
0.10% wt/vol.					-
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					
Not filtered					-
Filtered					-
Solids generated, gram					-
Dielectric Breakdown Voltage, 0.05 inch gap, °F, kv					ASTM D-877 (modi- fied). See Chap- ter 2. Test E-3
As received					See Chapter 2 Test E-5
With sea-water contamination:					-
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With carbon contamination:					See Chapter 2 Test E-6
0.10% wt/vol.					-
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					
Not filtered					-
Filtered					-
Solids generated, gram					-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi 65°-85° F					See Chapter 2 Test E-8
Number of tests					-
Operations to fixture (range)					-
<u>Emulsion Stability</u>					
Paddle Test, after 1-hour set- ting:					ASTM D-1401
Oil, ml	40				-
Emulsion, ml	1				-
Water, ml	40				-
Electric Probe Test, time for water separation, min					See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI*</u>					See Chapter 2 Test C-3
Butyl	Poor				-
Buna N	Fair				-
Viton B	Good				-
Ethylene-Propylene	Poor				-
Tetrafluoroethylene (Teflon)	Good				-
Neoprene	Poor				-
Thiokol	-				-
Silicone	Fair				-
Fluorosilicone	Good				-

\*Based on atmospheric pressure data.

				Method
Volatility		Synthetic		
Toxicity				
Density, grams/cubic centimeter, at:	35° F	100° F	150° F	
0 psig				
5,000 psig				See NSRDL Annapolis Report MATLAB 550
10,000 psig				
15,000 psig				
20,000 psig				
Isothermal Compressibility, volume decrease, %, at:	35° F	100° F	150° F	
0 psig				See NSRDL Annapolis Report MATLAB 550
5,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
Chemical Stability				
Oxidation Stability Test, 203° F, hours to failure				ASTM D-943
Oxidation Stability Test, 250° F				Fed. Method 570H
Hydrolytic Stability Test				Military specification MIL-H-19457B
Specimen change, mg				-
Specimen appearance				-
Fluid acid number increase, mg KOH/gram fluid				-
Water acidity, mg KOH				-
Insolubles, %				-
Thermal Stability Test				-
Fire Resistance				
Flash Point, °F	490			ASTM D-92
Fire Point, °F	550			ASTM D-92
Autogeneous Ignition Temperature, °F				ASTM D-2155
High-Pressure Spray Combustor				See NEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F				-
Minimum reaction temperature, °F				-
No indication of fire, °F				-
Maximum pressure change, psi				-
Lowest temperature of maximum pressure change, °F				-
Temperature range explored, °F				-
Miscellaneous Properties				
Pour Point, °F	<55			ASTM D-97
Foaming Tendency, 75° F				ASTM D-892
Foam after 5-minute aeration, ml	<25			-
Time out, minutes	1/2			-
Foam after 10-minute settling, ml	0			-
Neutralization Number, mg KOH/gram				ASTM D-974
Water Content, % by weight				ASTM D-1744
Neutrality, qualitative				Fed. Method 5101
Contamination				-
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP-598
25-100 micrometers				-
100-500 micrometers				-
over 500 micrometers				-
particles over 250 micrometers except fibers (length ten times diameter)				-
Gravimetric Value, mg/100 ml				SAE Method ARP-785
Specific gravity at 60/60°F	0.978			ASTM D-1298
Color				ASTM D-1500
Cost \$/gal	\$4.70			-
Availability	gov. spec.			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Supplementary Properties of MIL-L-23699A<sup>(1)</sup>

Material Compatibility with <sup>a</sup>		Method
Natural Rubber Polyurethane Buna S	Poor Poor Poor	See Chapter 2 Test C-3

<sup>a</sup>Based on atmospheric pressure data.

MIL-H-27601A

Suggested Uses and Possible Limitations

The fluid covered by MIL-H-27601A is a petroleum-base hydraulic fluid developed for use on high-velocity flight vehicles whose hydraulic components may be subjected to high temperatures. MIL-H-27601A is not suggested for any deep ocean applications until more information is available. Its viscosity is somewhat high, and atmospheric pressure corrosion tests indicate that the fluid provides little if any corrosion protection. Its dielectric properties have not been determined.

Properties of MIL-H-27601A<sup>(1)</sup>  
(Petroleum Base Fluid)

Viscometric Properties	35° F	100° F	150° F	Method
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
5,000 psig				MATLAB 750
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F,	15.11			
Viscosity, centistokes, at 210° F,	3.31			ASTM D-445
0 psig				-
Viscosity Slope, ASTM	0.793			-
Lubricating Ability				Fed. Method 600* (modified)
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:				-
1 kg				-
3 kg				-
5 kg				-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days				ASTM D-65
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg:				See Chapter 2 Test C-1
Copper	- 8.5			-
Stainless Steel, 316	+ 2.3			-
Copper-Nickel (70-30)	+ 6.9			-
Aluminum, QQ-A-250-4b	- 251.5			-
Phosphor-Bronze	- 96.6			-
Steel, galvanized	+ 101.7			-
Steel, 1009	- 1046.6			-
Aluminum, QQ-A-250-11	+ 117.1			-
Bronze	- 4.4			-
Monel	+ 1.5			-
Silver Base Brazing Alloy	+ 10.2			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

Corrosion Protection (Cont.)					
Method					
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1004	-				
Aluminum QQ-A-250-11 -	-				
Bronze	-				
Aluminum QQ-A-250-4b -	-				
Steel, 1009	-				
20,000 PSIG Stirred Corrosion					
Test, weight change, mg					
<u>Insulated Specimens:</u>					
Copper	-				
Stainless Steel, 316	-				
Copper-Nickel (70-30)	-				
Aluminum, QQ-A-250-4b	-				
Phosphor-Bronze	-				
Steel, galvanized	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11	-				
Bronze	-				
Monel	-				
Silver Base Brazing Alloy	-				
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum, QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11 -	-				
Bronze	-				
Aluminum, QQ-A-250-4b -	-				
Steel, 1009	-				
<u>Pump Test</u>					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					
Copper	-				
Aluminum	-				
Steel, galvanized	-				
Steel, 1009	-				
Silver Base Brazing Alloy	-				
<u>Dielectric Properties</u>					
Resistivity, $\sigma$ , ohm-cm:					
As-Received					
With Sea-Water Contamination:					
0.1% by volume	-				
0.5% by volume	-				
2.0% by volume	-				
With Carbon Contamination:					
0.1% wt/vol.	-				
0.25% wt/vol.	-				
0.5% wt/vol.	-				

		Method								
<u>Dielectric Properties (Cont)</u>										
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load										
Not filtered										
Filtered										
Solids generated, gram										
<u>Dissipation Factor, °F, %</u>										
As-Received										
With Sea-Water Contamination:										
0.1% by volume										
0.5% by volume										
2.0% by volume										
With Carbon Contamination:										
0.10% wt/vol.										
0.25% wt/vol.										
0.50% wt/vol.										
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load										
Not filtered										
Filtered										
Solids generated, gram										
<u>Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv</u>										
As received										
With sea-water contamination:										
0.1% by volume										
0.5% by volume										
2.0% by volume										
With carbon contamination:										
0.10% wt/vol.										
0.25% wt/vol.										
0.50% wt/vol.										
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load										
Not filtered										
Filtered										
Solids generated, gram										
<u>Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F</u>										
Number of tests										
Operations to failure (range)										
<u>Emulsion Stability</u>										
Paddle Test, after 1-hour set- tling:										
Oil, ml		40								
Emulsion, ml		0								
Water, ml		40								
Electric Probe Test, time for water separation, min										
<u>Material Compatibility, Static 20K PSI*</u>										
Butyl		Poor								
Buna N		Good								
Viton B		Good								
Ethylene-Fropylene		Poor								
Tetrafluoroethylene (Teflon)		Good								
Neoprene		Fair								
Thiokol		-								
Silicone		Fair								
Fluorosilicone		Fair								

\* Based on atmospheric pressure data.

					Method
		Petroleum	100° F	150° F	
<u>Volatility</u>					-
<u>Toxicity</u>					-
<u>Density, grams/cubic centimeter, at:</u>		35° F	100° F	150° F	See NSRDL Annapolis Report MATLAB 350
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, at:</u>		35° F	100° F	150° F	See NSRDL Annapolis Report MATLAB 350
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					Fed. Method 5308
Hydrolytic Stability Test					Military specification MIL-H-19457B
Specimen change, mg		0.01			-
Specimen appearance		0.02			-
Fluid acid number increase, mg KOH/gram fluid		0.41			-
Water acidity, mg KOH		Nil			-
Insolubles, %					-
Thermal Stability Test					-
<u>Fire Resistance</u>					
Flash Point, °F	390				ASTM D-92
Fire Point, °F	420				ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combustor					See MEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Pour Point, °F	<65				ASTM D-97
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gm					ASTM D-974
Water Content, % by weight	0.007				ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml	0.844				SAE Method ARP-785
Specific gravity at 70/60°F					ASTM D-1298
Color					ASTM D-1500
Cost \$/gal	\$65.00				-
Availability	gov. spec.				-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Supplementary of Properties of MIL-H-27601A<sup>(1)</sup>

<u>Material Compatibility with*</u>		<u>Method</u>
Buna S	Poor	See Chapter 2
Natural Rubber	Poor	Test C-3
Polyurethane	Good	

\* Based on atmospheric pressure data.

MIL-H-46004

Suggested Uses and Possible Limitations

The fluid described by MIL-H-46004 is a petroleum-base hydraulic fluid developed for use in missiles where low temperatures are anticipated. The atmospheric pressure viscosity of MIL-H-46004 indicates that it might be satisfactory at a depth capability of 20,000 feet. This fluid provides no corrosion protection, and it is highly flammable. Its lubrication and electrical properties have not been measured.

**Properties of MIL-H-46004<sup>(1)</sup>  
(Petroleum Base Fluid)**

				Method
Viscometric Properties	50° C	100° C	210° F	
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
6,000 psig				MATLAB <sup>(2)</sup>
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F,	2.88			
Viscosity, centistokes, at 210° F,	1.21			ASTM D-441
0 psig				-
Viscosity Slope, ASTM	0.741			-
<b>Lubricating Ability</b>				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				Fed. Method E105 (modified)
1 kg				-
3 kg				-
5 kg				-
<b>Corrosion Protection</b>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-661
On-Oil Rust Test, 40% seawater, 140° F, 30 days				See Chapter 1 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 1 Test C-1
Copper	- 29.2			-
Stainless Steel, 316	+ 0.6			-
Copper-Nickel (70-30)	- 0.4			-
Aluminum, QQ-A-250-4b	- 132.7			-
Phosphor-Bronze	- 6.8 <sup>(2)</sup>			-
Steel, galvanized	- 1194.1			-
Steel, 1009	- 1369.5			-
Aluminum, QQ-A-250-11	- 147.8			-
Bronze	- 15.7			-
Monel	- 1.5			-
Silver Base Braze Alloy	- 19.1			-
20,000 PSIG Pressure-Cycled Corrosion Test (1" seawater), weight change, mg				See Chapter 1 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Braze Alloy				-

Corrosion Protection (Cont.)						Method
Electrically Coupled Specimens:						-
Copper-Aluminum, QQ-A-250-11						-
Aluminum QQ-A-250-4b -						-
Copper-Nickel (70-30)						-
Monel-Bronze						-
Stainless Steel (316) -						-
Phosphor-Bronze						-
Silver Base Brazing Alloy -						-
Steel, 1004						-
Aluminum QQ-A-250-11 -						-
Bronze						-
Aluminum QQ-A-250-4b -						-
Steel, 1009						-
20,000 PSIG Stirred Corrosion						See Chapter 2 Test C-4
Test, weight change, mg						
Insulated Specimens:						
Copper						-
Stainless Steel, 316						-
Copper-Nickel (70-30)						-
Aluminum, QQ-A-250-4b						-
Phosphor-Bronze						-
Steel, galvanized						-
Steel, 1009						-
Aluminum, QQ-A-250-11						-
Bronze						-
Monel						-
Silver Base Brazing Alloy						-
Electrically Coupled Specimens:						
Copper-Aluminum, QQ-A-250-11						-
Aluminum, QQ-A-250-4b -						-
Copper-Nickel (70-30)						-
Monel-Bronze						-
Stainless Steel (316) -						-
Phosphor-Bronze						-
Silver Base Brazing Alloy -						-
Steel, 1009						-
Aluminum, QQ-A-250-11 -						-
Bronze						-
Aluminum, QQ-A-250-4b -						-
Steel, 1009						-
Pump Test						
Average Weight Loss, mg						
Steel Gears						
Bronze Bushings						
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>						
Copper						-
Aluminum						-
Steel, galvanized						-
Steel, 1009						-
Silver Base Brazing Alloy						-
Dielectric Properties						
Resistivity, $\text{F}$ , ohm-cm:						
As-Received						
With Sea-Water Contamination:						
0.1% by volume						
0.5% by volume						
2.0% by volume						
With Carbon Contamination:						
0.1% wt/vol.						
0.25% wt/vol.						
0.5% wt/vol.						

		Method								
<u>Dielectric Properties (Cont.)</u>										
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load										
Not filtered										
Filtered										
Solids generated, gram										
Dissipation Factor, °F. %										
As-Received										
With Sea-Water Contamination:										
0.1% by volume										
0.5% by volume										
2.0% by volume										
With Carbon Contamination:										
0.10% wt/vol.										
0.25% wt/vol.										
0.50% wt/vol.										
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load										
Not filtered										
Filtered										
Solids generated, gram										
Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv										
As received										
With sea-water contamination:										
0.1% by volume										
0.5% by volume										
2.0% by volume										
With carbon contamination:										
0.10% wt/vol.										
0.25% wt/vol.										
0.50% wt/vol.										
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load										
Not filtered										
Filtered										
Solids generated, gram										
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F										
Number of tests										
Operations to failure (range)										
<u>Emulsion Stability</u>										
Paddle Test, after 1-hour set- tling:										
Oil, ml		40								
Emulsion, ml		0								
Water, ml		40								
Electric Probe Test, time for water separation, min										
<u>Material Compatibility Static 20KPSI</u>										
Butyl		Poor								
Buna N		Good								
Viton B		Good								
Ethylene-Propylene		Poor								
Tetrafluoroethylene (Teflon)		Good								
Neoprene		Fair								
Thiokol		-								
Silicone		Fair								
Fluorosilicone		Fair								

\* Based on atmospheric pressure data.

Volatility		Petroleum				Method
Toxicity			50° F	100° F	150° F	
Density, grams/cubic centimeter, atm:						
0 psig	52					
3,000 psig						
5,000 psig						
8,000 psig						
10,000 psig						
15,000 psig						
20,000 psig						
Isothermal Compressibility, volume decrease, %, atm:		50° F	100° F	150° F		
0 psig						
3,000 psig						
5,000 psig						
8,000 psig						
10,000 psig						
15,000 psig						
20,000 psig						
Chemical Stability						
Oxidation Stability Test, 203° F, hours to failure						ASTM D-943
Oxidation Stability Test, 250° F						
Hydrolytic Stability Test						
Specimen change, mg						Fed. Method 5308
Specimen appearance						Military specification MIL-H-19457B
Fluid acid number increase, mg KOH/gram fluid						-
Water acidity, mg KOH						-
Insolubles, %						-
Thermal Stability Test						-
Fire Resistance						-
Flash Point, °F	210					ASTM D-92
Fire Point, °F	220					ASTM D-92
Autogeneous Ignition Temperature, °F						ASTM D-2155
High-Pressure Spray Combustor						See NEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F						-
Minimum reaction temperature, °F						-
No indication of fire, °F						-
Maximum pressure change, psi						-
Lowest temperature of maximum pressure change, °F						-
Temperature range explored, °F						-
Miscellaneous Properties						
Pour Point, °F	<75					ASTM D-97
Foaming Tendency, 75° F						ASTM D-892
Foam after 5-minute aeration, ml						-
Time out, minutes						-
Foam after 10-minute settling, ml						-
Neutralization Number, mg KOH/gram						ASTM D-974
Water Content, % by weight						ASTM D-1744
Neutrality, qualitative						Fed. Method 5101
Contamination						-
Number and size of particles and fibers in 100-ml fluid						SAE Method ARP-598
25-100 micrometers						-
100-500 micrometers						-
over 500 micrometers						-
particles over 250 micrometers except fibers (length ten times diameter)						-
Gravimetric Value, mg/100 ml						SAE Method ARP-785
Specific gravity at 70/60° F	0.850					ASTM D-1298
Color						ASTM D-1500
Cost \$/gal	\$2.00					-
Availability	gov. spec.					

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>2</sup>Heavy deposits indicates corrosion not shown by weight change.

## Supplementary Properties of MIL-H-46004

<u>Material Compatibility with:</u>		Method
Buna S	Poor	See Chapter 2
Natural Rubber	Poor	Test C-5
Polyurethane	Good	

\* Based on atmospheric pressure data.

Suggested Uses and Possible Limitations

The fluid covered by MIL-H-81019B is a petroleum-base hydraulic fluid for use in aircraft, missiles, and ordnance hydraulic systems in the -90° to +210° F temperature range. MIL-H-81019B appears to have properties for use at great depth. Its viscosity appears to be too low at atmospheric pressure for use as a general-purpose lubricant. It provides some degree of corrosion inhibition, and it is highly flammable. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

**Properties of MIL-H-81019B<sup>(1)</sup>**  
**(Petroleum Base Fluid)**

Viscometric Properties	15° F	100° F	150° F	Method
Viscosity, centistokes, at:				
0 psig				See NSKDL
3,000 psig				Annapolis Report
5,000 psig				NATLAB 550
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				
Viscosity, centistokes, at 100° F.	7.20			
Viscosity, centistokes, at 210° F.	2.82			ASTM D-445
0 psig				-
Viscosity Slope, ASTM	0.565			
Lubricating Ability				Fed. Method 6503 (modified)
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia.:				-
mm:				-
1 kg				-
3 kg				-
5 kg				-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass			ASTM D-655
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-1.0			-
Stainless Steel, 316	-0.1			-
Copper-Nickel (70-30)	-0.5			-
Aluminum, QQ-A-250-4b	0			-
Phosphor-Bronze	-0.4			-
Steel, galvanized	-0.3			-
Steel, 1009	0			-
Aluminum, QQ-A-250-11	0			-
Bronze	-0.5			-
Monel	-0.2			-
Silver Base Brazing Alloy	-0.4			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

Corrosion Protection (Cont.)						Method
Electrically Coupled Specimens: Copper-Aluminum, QQ-A-250-11 Aluminum QQ-A-250-4b - Copper-Nickel (70-30) Monel-Bronze Stainless Steel (316) - Phosphor-Bronze Silver Base Braze Alloy - Steel, 1004 Aluminum QQ-A-250-11 - Bronze Aluminum QQ-A-250-4b - Steel, 1009						-
20,000 PSIG Stirred Corrosion Test, weight change, mg						See Chapter 2 Test C-4
Insulated Specimens: Copper Stainless Steel, 316 Copper-Nickel (70-30) Aluminum, QQ-A-250-4b Phosphor-Bronze Steel, galvanized Steel, 1009 Aluminum, QQ-A-250-11 Bronze Monel Silver Base Braze Alloy						-
Electrically Coupled Specimens: Copper-Aluminum, QQ-A-250-11 Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) Monel-Bronze Stainless Steel (316) - Phosphor-Bronze Silver Base Braze Alloy - Steel, 1009 Aluminum, QQ-A-250-11 - Bronze Aluminum, QQ-A-250-4b - Steel, 1009						-
Pump Test Average Weight Loss, mg Steel Gears Bronze Bushings						Proposed military specification for sea-water emulsi- fying oils
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup> Copper Aluminum Steel, galvanized Steel, 1009 Silver Base Braze Alloy	2.6x10 <sup>11</sup>					ASTM D-1169 (mod- ified). See Chap- ter 2, Test E-1 Chapter 2 Test E-5
Dielectric Properties Resistivity, 76° F, ohm-cm: As-Received With Sea-Water Contamination: 0.1% by volume 0.5% by volume 2.0% by volume With Carbon Contamination: 0.1% wt/vol. 0.25% wt/vol. 0.5% wt/vol.						Chapter 2 Test E-6

		Method				
<u>Dielectric Properties (Cont)</u>						
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Dissipation Factor, 76 °F, %						
As-Received		1.3				
With Sea-Water Contamination:						
0.1% by volume						
0.5% by volume						
2.0% by volume						
With Carbon Contamination:						
0.10% wt/vol.						
0.25% wt/vol.						
0.50% wt/vol.						
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Dielectric Breakdown Voltage, 0.05-inch gap, 76 °F kv						
As received		22.4				
With sea-water contamination:						
0.1% by volume						
0.5% by volume						
2.0% by volume						
With carbon contamination:						
0.10% wt/vol.						
0.25% wt/vol.						
0.50% wt/vol.						
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						
Number of tests						
Operations to failure (range)						
<u>Emulsion Stability</u>						
Paddle Test, after 1-hour set- tling:						
Oil, ml		28				
Emulsion, ml		48				
Water, ml		4				
Electric Probe Test, time for water separation, min						
<u>Material Compatibility Static 20KPSI</u>						
Butyl		Poor				
Buna N		Good				
Viton B		Good				
Ethylene-Propylene		Poor				
Tetrafluoroethylene (Teflon)		Good				
Neoprene		Fair				
Thiokol		-				
Silicone		Fair				
Fluorosilicone		Fair				

\* Based on atmospheric pressure data.

<u>Volatility</u>		Petroleum	35° F	100° F	150° F		<u>Method</u>
<u>Toxicity</u>							-
Density, grams/cubic centimeter, at:	0 psig						See NSRDL Annapolis Report MATLAB 350
	3,000 psig						
	5,000 psig						
	8,000 psig						
	10,000 psig						
	15,000 psig						
	20,000 psig						
Isothermal Compressibility, volume decrease, %, at:	0 psig						See NSRDL Annapolis Report MATLAB 350
	3,000 psig						
	5,000 psig						
	8,000 psig						
	10,000 psig						
	15,000 psig						
	20,000 psig						
Chemical Stability							
Oxidation Stability Test, 203° F, hours to failure							ASTM D-943
Oxidation Stability Test, 250° F							Fed. Method 5308
Hydrolytic Stability Test							Military specification MIL-H-19457B
Specimen change, mg							-
Specimen appearance							-
Fluid acid number increase, mg KOH/gram fluid							-
Water acidity, mg KOH							-
Insolubles, %							-
Thermal Stability Test							-
Fire Resistance							-
Flash Point, °F		212					ASTM D-92
Fire Point, °F		225					ASTM D-92
Autogeneous Ignition Temperature, °F							ASTM D-2155
High-Pressure Spray Combustor							See NEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F							-
Minimum reaction temperature, °F							-
No indication of fire, °F							-
Maximum pressure change, psi							-
Lowest temperature of maximum pressure change, °F							-
Temperature range explored, °F							-
Miscellaneous Properties							
Pour Point, °F		<90					ASTM D-97
Poaming Tendency, 75° F							ASTM D-892
Foam after 5-minute aeration, ml							-
Time out, minutes							-
Foam after 10-minute settling, ml							-
Neutralization Number, mg KOH/gram							ASTM D-974
Water Content, % by weight							ASTM D-1744
Neutrality, qualitative							Fed. Method 5101
Contamination							-
Number and size of particles and fibers in 100-ml fluid							SAE Method ARP-598
25-100 micrometers							-
100-500 micrometers							-
over 500 micrometers							-
particles over 250 micrometers except fibers (length ten times diameter)							-
Gravimetric Value, mg/100 ml		0.858					SAE Method ARP-785
Specific Gravity at 70/60 °F							ASTM D-1298
Color							ASTM D-1500
Cost \$/gal			Available from supplier				-
Availability	gov. spec.						-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Supplementary of Properties of MIL-H-81019B<sup>(1)</sup>

Material Compatibility with:		Method
Buna S	Poor	See Chapter 2
Natural Rubber	Poor	Test C.3
Polyurethane	Good	

\* Based on atmospheric pressure data.

PROPRIETARY FLUIDS

III-115

### Fluid Code A

#### Suggested Uses and Possible Limitations

Fluid Code A, a sea-water emulsifying hydraulic fluid, Grade 1, petroleum-base oil, has the same viscosity as MIL-L-17672, MS 2110-TH, which is too high for most deep ocean applications. It has good lubricating properties and good corrosion-inhibiting properties. Its dielectric properties are questionable for deep ocean applications in that it has a low resistivity and a high dissipation factor.

Fluid Code A<sup>(1)</sup>  
(Petroleum Base Fluid)

Viscometric Properties	55° F	100° F	150° F	Method	
				See NSRDL Annapolis Report MATLAB 3.0	- - -
Viscosity, centistokes, at:					
0 psig					
5,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
Viscosity, centistokes, at 100° F,	41.9				
Viscosity, centistokes, at 210° F,	5.93				
0 psig					
Viscosity Slope, ASTM	0.768				
Lubricating Ability					
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:	Dry	Dry	1% Seawater	1% Seawater	Fed. Method 650 <sup>1</sup> (modified)
5 kg	Dry Argon	Dry Oxygen	Wet Argon	Wet Oxygen	
10 kg	0.16	-	0.36	-	-
20 kg	0.26	0.24	0.38	0.48	-
30 kg	0.29	-	0.41	0.50	-
	0.34	0.32	0.45	0.66	-
Corrosion Protection					
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass				ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Pass				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg					See Chapter 2 Test C-1
Copper	-69.5				-
Stainless Steel, 316	- 0.2				-
Copper-Nickel (70-30)	- 0.1				-
Aluminum, QQ-A-250-4b	+ 0.1				-
Phosphor-Bronze	- 1.0				-
Steel, galvanized	- 2.6				-
Steel, 1009	+ 0.1				-
Aluminum, QQ-A-250-11	+ 0.1				-
Bronze	- 1.2				-
Monel	- 0.3				-
Silver Base Brazing Alloy	-72.4				-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg					See Chapter 2 Test C-2
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Brazing Alloy					-

Corrosion Protection (Cont.)						Method
Electrically Coupled Specimens:						-
Copper-Aluminum, QQ-A-250-11						-
Aluminum QQ-A-250-4b -						-
Copper-Nickel (70-30)						-
Monel-Bronze						-
Stainless Steel (316) -						-
Phosphor-Bronze						-
Silver Base Brazing Alloy -						-
Steel, 1004						-
Aluminum QQ-A-250-11 -						-
Bronze						-
Aluminum QQ-A-250-4b -						-
Steel, 1009						-
20,000 PSIG Stirred Corrosion						See Chapter 2 Test C-4
Test, weight change, mg						
Insulated Specimens:						
Copper						-
Stainless Steel, 316						-
Copper-Nickel (70-30)						-
Aluminum, QQ-A-250-4b						-
Phosphor-Bronze						-
Steel, galvanized						-
Steel, 1009						-
Aluminum, QQ-A-250-11						-
Bronze						-
Monel						-
Silver Base Brazing Alloy						-
Electrically Coupled Specimens:						-
Copper-Aluminum, QQ-A-250-11						-
Aluminum, QQ-A-250-4b -						-
Copper-Nickel (70-30)						-
Monel-Bronze						-
Stainless Steel (316) -						-
Phosphor-Bronze						-
Silver Base Brazing Alloy -						-
Steel, 1009						-
Aluminum, QQ-A-250-11 -						-
Bronze						-
Aluminum, QQ-A-250-4b -						-
Steel, 1009						-
Pump Test						
Average Weight Loss, mg						
Steel Gears	3					
Bronze Bushings	1					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>	-					
Copper	0.40					
Aluminum	0.01					
Steel, galvanized	0.02					
Steel, 1009	0.01					
Silver Base Brazing Alloy	0.51					
Dielectric Properties						
Resistivity, 77°F, ohm-cm:						
As-Received						
With Sea-Water Contamination:						ASTM D-1164 (modi- fied). See Chap- ter 2, Test E-1
0.1% by volume						
0.5% by volume						
2.0% by volume						
With Carbon Contamination:						Chapter 2 Test E-4
0.1% wt/vol.						
0.25% wt/vol.						
0.5% wt/vol.						

		Method				
<u>Dielectric Properties (Cont.)</u>						
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 2 Test E-7
Not filtered						-
Filtered						-
Solids generated, gram						-
Dissipation Factor, 77°F, %						See Chapter 2 Test E-2
As-Received						-
With Sea-Water Contamination:						See Chapter 2 Test E-3
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With Carbon Contamination:						See Chapter 2 Test E-6
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						-
Dielectric Breakdown Voltage, 0.05-inch gap, 77°F, kV						ASTM D-2877 (modified). See Chapter 2, Test E-3
As received						See Chapter 2 Test E-5
With sea-water contamination:						-
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With carbon contamination:						See Chapter 2 Test E-6
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						See Chapter 2 Test E-3
Number of tests						-
Operations to failure (range)						-
<u>Emulsion Stability</u>						
Paddle Test, after 1-hour set- tling:						ASTM D-1401
Oil, ml	0					-
Emulsion, ml	80					-
Water, ml	0					-
Electro Probe Test, time for water separation, min						See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>						See Chapter 2 Test C-3
Butyl	Poor					-
Buna N	Good					-
Viton B	Good					-
Ethylene-Propylene	Poor					-
Tetrafluoroethylene (Teflon)	Good					-
Neoprene	Fair					-
Thiokol	-					-
Silicone	Fair					-
Fluorosilicone	Fair					-

\* Based on atmospheric pressure data.

Method				
	Petroleum	100° F	100° F	
<u>Volatility</u>				
<u>Toxicity</u>				
<u>Density, grams/cubic centimeter, at</u>				
0 psig				
3,000 psig				See MIL-STD-883C, Annex 10, Method 2001
5,000 psig				MATLAB™
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Isothermal Compressibility, volume</u>	35° F	100° F	100° F	
<u>decrease, %, at</u>				
0 psig				See MIL-STD-883C, Annex 10, Method 2001
3,000 psig				MATLAB™
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Chemical Stability</u>				
<u>Oxidation Stability Test, 203° F, hours to failure</u>	525			ASTM D-942
<u>Oxidation Stability Test, 250° F</u>				Fed. Method 1774
<u>Hydrolytic Stability Test</u>				Military specification MIL-H-19457B
Specimen change, mg				
Specimen appearance				
Fluid acid number increase, mg KOH/gram fluid				
Water acidity, mg KOH				
Insolubles, %				
<u>Thermal Stability Test</u>				
<u>Fire Resistance</u>				
<u>Flash Point, °F</u>	375			ASTM D-93
<u>Fire Point, °F</u>	430			ASTM D-93
<u>Autogeneous Ignition Temperature, °F</u>				ASTM D-2156
<u>High-Pressure Spray Combustor</u>				See MIL-Report 21/66 of March 1967
Minimum spontaneous ignition temperature, °F				
Minimum reaction temperature, °F				
No indication of fire, °F				
Maximum pressure change, psi				
Lowest temperature of maximum pressure change, °F				
Temperature range explored, °F				
<u>Miscellaneous Properties</u>				
<u>Pour Point, °F</u>	-10			ASTM D-97
<u>Foaming Tendency, 75° F</u>				ASTM D-890
Foam after 5-minute aeration, ml	<10			
Time out, minutes	0			
Foam after 10-minute settling, ml	0			
<u>Neutralization Number, mg KOH/gram</u>	0.9			ASTM D-974
<u>Water Content, % by weight</u>	0.076			ASTM D-1744
<u>Neutrality, qualitative</u>	Neutral			Fed. Method 1101
<u>Contamination</u>				
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP-598
25-100 micrometers	582			
100-500 micrometers	6			
over 500 micrometers				
particles over 250 micrometers except fibers (length ten times diameter)	0			
<u>Gravimetric Value, mg/10C ml</u>	8.9			SAE Method ARP-786
<u>Specific gravity, 60/60 °F</u>	0.889			ASTM D-1298
<u>Color</u>	3.5			ASTM D-1500
<u>Cost \$/gal</u>				
<u>Availability</u>	Available from supplier proprietary			

Determinations made at atmospheric pressure, unless noted.

## Fluid Code A

Material Compatibility with:		Method
Buna S	Poor	See Chapter
Natural Rubber	Poor	Test C-3
Polyurethane	Good	

\* Based on atmospheric pressure data.

Fluid Code B

Suggested Uses and Possible Limitations

Fluid Code B, a petroleum oil product, was originally developed for missile use. Its viscosity at atmospheric pressure is too low for a general lubrication or hydraulic fluid over sustained time periods; however, it would be in the right viscosity range at great depths. It provides excellent corrosion inhibition for ferrous metals but provides no protection for nonferrous metals. Its electrical resistivity is low and its dissipation factor is very high, making it questionable for known deep ocean electrical application. It is extremely flammable.

Fluid Code 8<sup>(1)</sup>  
(Petroleum Base Fluid)

Viscometric Properties	50° F	100° F	150° F	Method
				See NSRDL Annapolis Report MATLAB 350
Viscosity, centistokes, at 0 psig 1,000 psig 5,000 psig 10,000 psig 15,000 psig 20,000 psig				- - - - -
Viscosity, centistokes, at 100° F, Viscosity, centistokes, at 210° F, 0 psig	3.42 1.36			ASTM D-445
Viscosity Slope, ASTM	0.893			-
Lubricating Ability				Fed. Method 6503 (modified)
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average wear dia., mm: 1 kg 3 kg 5 kg				- - -
Corrosion Protection	Pass			ASTM D-665
Stirred Rust Test, 10% seawater, 140° F, 2 days				See Chapter 2 Test C-5
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter 2 Test C-1
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				
Copper	-39.2			-
Stainless Steel, 316	+ 0.2			-
Copper-Nickel (70-30)	- 3.8			-
Aluminum, QQ-A-250-4a	+ 0.4			-
Phosphor-Bronze	-17.8			-
Steel, galvanized	-16.8			-
Steel, 1009	- 0.2			-
Aluminum, QQ-A-250-11	+ 0.3			-
Bronze	-20.9			-
Mnol	- 0.2			-
Silver Base Brazing Alloy	-10.2			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4a				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Mnol				-
Silver Base Brazing Alloy				

		Method			
<u>Corrosion Protection (Cont.)</u>					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 RSD Stirred Corrosion					See Chapter 1
Test, weight change, mg					Test C-4
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Braze Alloy					-
Electrically Coupled Specimens:					-
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
Pump Test					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss,					
each, mg/cm <sup>2</sup>					
Copper					
Aluminum					
Steel, galvanized					
Steel, 1009					
Silver Base Braze Alloy					
<u>Dielectric Properties</u>					
Resistivity, 76 °F, ohm-cm:		1.0x10 <sup>9</sup>			
As-Received					
With Sea-Water Contamination:					
0.1% by volume					
0.5% by volume					
2.0% by volume					
With Carbon Contamination:					
0.1% wt/vol.					
0.25% wt/vol.					
0.5% wt/vol.					

<u>Dielectric Properties (Cont)</u>		Method			
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					See Chapter 2 Test E-7
Not filtered					-
Filtered					-
Solids generated, gram					-
Dissipation Factor, 76°F, %					See Chapter 2
As-Received					Test E-2
With Sea-Water Contamination:					See Chapter 2
0.1% by volume					- Test E-5
0.5% by volume					-
2.0% by volume					-
With Carbon Contamination:					See Chapter 2
0.10% wt/vol.					Test E-6
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					-
Not filtered					-
Filtered					-
Solids generated, gram					-
Dielectric Breakdown Voltage, 0.05-inch gap, 76°F, kv	25.4				ASTM D-877 (modified). See Chapter 2. Test E-3
As received					See Chapter 2
With sea-water contamination:					Test E-5
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With carbon contamination:					See Chapter 2
0.10% wt/vol.					Test E-6
0.25% wt/vol.					-
0.50% wt/vol.					-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					-
Not filtered					-
Filtered					-
Solids generated, gram					-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F					See Chapter 2
Number of tests					Test E-8
Operations to failure (range)					-
<u>Emulsion Stability</u>					
Paddle Test, after 1-hour set- tling:					ASTM D-1401
Oil, ml	23				-
Emulsion, ml	57				-
Water, ml	0				-
Electric Probe Test, time for water separation, min					See Chapter 2
<u>Material Compatibility</u> Static 20KPSI					Test E-4
Butyl					See Chapter 2
Bun N					Test C-5
Viton B					-
Ethylene-Propylene					-
Tetrafluoroethylene (Teflon)					-
Neoprene					-
Thiokol					-
Silicone					-
Fluorosilicone					-

<u>Volatility</u>		<u>Petroleum</u>			<u>Method</u>
<u>Toxicity</u>					
Density, grams/cubic centimeter, at:	35° F	100° F	150° F		
0 psig					See NSRDL Annapolis Report MATLAB 350
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, at:</u>	35° F	100° F	150° F		
0 psig					See NSRDL Annapolis Report MATLAB 350
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					Fed. Method 1303
Hydrolytic Stability Test					Military specification MIL-H-19457B
Specimen change, mg		0.12			-
Specimen appearance		Satisfactory			-
Fluid acid number increase, mg KOH/gram fluid		0.21			-
Water acidity, mg KOH		10			-
Insolubles, %		nil			-
Thermal Stability Test					-
<u>Fire Resistance</u>					
Flash Point, °F	205				ASTM D-92
Fire Point, °F	215				ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2112
High-Pressure Spray Combustor					See MIL-STD-51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Pour Point, °F					ASTM D-97
Foaming Tendency, 75° F					ASTM D-240
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram	0.09				ASTM D-2774
Water Content, % by weight					ASTM D-1744
Neutrality, qualitative					Fed. Method 1303
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-198
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-198
Specific gravity at 70/70 °F	0.852				ASTM D-116
Color					ASTM D-116
Cost \$/gal		Available from supplier			-
Availability		proprietary			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Fluid Code C

Suggested Uses and Possible Limitations

As a petroleum oil product, Fluid Code C has viscosity properties similar to those of MIL-H-46004 and has been used as an immersion medium for electric motors at pressures corresponding to a depth capability of 20,000 feet. Its viscosity is too low at atmospheric pressure to consider it as a general lubricant over sustained periods of time. It shows good corrosion inhibition for both ferrous and nonferrous metals. It has a low electrical resistivity and a high dissipation factor, making it questionable for any known deep ocean electrical application. It is extremely flammable.

**Fluid Code C<sup>(1)</sup>**  
**(Petroleum Base Fluid)**

Viscometric Properties	50° F (2)			Method
		100° F	150° F	
Viscosity, centistokes, at:				
0 psig	12			
3,000 psig	17			
5,000 psig	22			
8,000 psig	32			
10,000 psig	42			
15,000 psig	82			
20,000 psig	180			
Viscosity, centistokes, at 100° F,	3.73			
Viscosity, centistokes, at 210° F,	1.41			
0 psig				
Viscosity Slope, ASTM	0.825			
Lubricating Ability				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				Fed. Method C-5 (modified)
1 kg	0.18			-
3 kg	0.25 (scuffing, oil film lost)			-
5 kg	0.30 (scuffing, oil film lost)			-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass			ASTM I-174-71
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter I Test C-1
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter I Test C-1
Copper	-17.8			-
Stainless Steel, 316	+ 0.3			-
Copper-Nickel (70-30)	- 0.4			-
Aluminum, QQ-A-250-4b	+ 0.6			-
Phosphor-Bronze	- 5.5			-
Steel, galvanized	- 0.2			-
Steel, 1009	+ 0.2			-
Aluminum, QQ-A-250-11	+ 0.4			-
Bronze	- 5.6			-
Monel	+ 0.2			-
Silver Base Brazing Alloy	- 5.2			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter I Test C-1
Insulated Specimen:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

				Method
<u>Corrosion Protection (Cont)</u>				
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				-
Aluminum QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Brazing Alloy -				-
Steel, 1004				-
Aluminum QQ-A-250-11 -				-
Bronze				-
Aluminum QQ-A-250-4b -				-
Steel, 1009				-
20,000 PSIG Stirred Corrosion Test, weight change, mg	(10% seawater)			See Chapter 1 Test C-4
Insulated Specimens:				
Copper	-1.4			-
Stainless Steel, 316	-1.3			-
Copper-Nickel (70-30)	-0.3			-
Aluminum, QQ-A-250-4b	+0.1			-
Phosphor-Bronze	+0.1			-
Steel, galvanized	-0.2			-
Steel, 1009	-0.3			-
Aluminum, QQ-A-250-11	+0.2			-
Bronze	-1.3			-
Monel	-2.1			-
Silver Base Brazing Alloy	-4.7			-
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11	-2.2 +L			-
Aluminum, QQ-A-250-4b -				-
Copper-Nickel (70-30)	-0.3 -0.5			-
Monel-Bronze	+0.2 +0.6			-
Stainless Steel (316) -				-
Phosphor-Bronze	+0.8 +0.7			-
Silver Base Brazing Alloy -				-
Steel, 1009	+0.2 +0.1			-
Aluminum, QQ-A-250-11 -	+1.2 +0.5			-
Bronze				-
Aluminum, QQ-A-250-4b -	+0.1 -0.1			-
Steel, 1009				-
Pump Test				
Average Weight Loss, mg				
Steel Gears				
Bronze Bushings				
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>				
Copper				-
Aluminum				-
Steel, galvanized				-
Steel, 1009				-
Silver Base Brazing Alloy				-
Dielectric Properties				
Resistivity, 77°F, ohm-cm:	4.0x10 <sup>8</sup>			
As-Received				
With Sea-Water Contamination:				
0.1% by volume				
0.5% by volume				
2.0% by volume				
With Carbon Contamination:				
0.1% wt/vol.				
0.25% wt/vol.				
0.5% wt/vol.				

						Method
<u>Dielectric Properties (Cont.)</u>						
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 1 Test E-7
Not filtered						-
Filtered						-
Solids generated, gram						-
Dissipation Factor, 77 °F, %						See Chapter 1 Test E-2
As-Received	>60					See Chapter 2 - Test E-5
With Sea-Water Contamination:						-
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With Carbon Contamination:						See Chapter 2 Test E-6
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Dielectric Breakdown Voltage, 0.05-inch gap, 77 °F, kv						ASTM D-877 (modified). See Chapter 2. Test E-3
As received	28.4					See Chapter 2 Test E-5
With sea-water contamination:						-
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With carbon contamination:						See Chapter 2 - Test E-6
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						
Not filtered						
Filtered						
Solids generated, gram						
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						See Chapter 1 Test E-3
Number of tests						-
Operations to failure (range)						-
<u>Emulsion Stability</u>						
Paddle Test, after 1-hour set- tling:						ASTM D-1401
Oil, ml	25					-
Emulsion, ml	55					-
Water, ml	0					-
Electric Probe Test, time for water separation, min						See Chapter 1 Test E-4
<u>Material Compatibility Static 2CKPSI</u>						See Chapter 1 Test C-3
Butyl						-
Buna N						-
Viton B						-
Ethylene-Propylene						-
Tetrafluoroethylene (Teflon)						-
Neoprene						-
Thiokol						-
Silicone						-
Fluorosilicone						-

Volatility		Petroleum	52° F	73° F	150° F	Method	
Tensile	Pressure					-	-
Density, grams/cubic centimeter, at:							
0 psig	0.860	0.852					
3,000 psig	0.871	0.864					
5,000 psig	0.879	0.872					
8,000 psig	0.888	0.882					
10,000 psig	0.896	0.889					
15,000 psig	0.909	0.903					
20,000 psig	0.923	0.917					
Compressibility, volume decrease, %, at:		52° F	73° F	100° F			
0 psig							
3,000 psig	1.4	1.5	1.7				
5,000 psig	2.2	2.3	2.6				
8,000 psig	3.3	3.5	3.8				
10,000 psig	3.9	4.2	4.6				
15,000 psig	5.5	5.7	6.3				
20,000 psig	6.8	7.1	7.8				
Chemical Stability							
Oxidation stability Test, 203° F, hours to failure							ASTM D-943
Oxidation stability Test, 250° F							Fed. Method 5308
Hydrolytic Stability Test							Military specification MIL-H-19457B
Specimen change, mg							-
Specimen appearance							-
Fluid acid number increase, mg KOH/gram fluid							-
Water acidity, mg KOH							-
Insolubles, %							-
Thermal Stability Test							-
Fire Resistance							
Flash Point, °F	200						ASTM D-92
Fire Point, °F	220						ASTM D-92
Autogeneous Ignition Temperature, °F							ASTM D-2155
High-Pressure Spray Combustor							See MEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F							-
Minimum reaction temperature, °F							-
No indication of fire, °F							-
Maximum pressure change, psi							-
Lowest temperature of maximum pressure change, °F							-
Temperature range explored, °F							-
Miscellaneous Properties							
Pour Point, °F	<90						ASTM D-97
Foaming Tendency, 75° F							ASTM D-807
Foam after 5-minute aeration, ml							-
Time out, minutes							-
Foam after 10-minute settling, ml							-
Neutralization Number, mg KOH/gram	0.09						ASTM D-974
Water Content, % by weight							ASTM D-1744
Neutrality, qualitative							Fed. Method 5101
Contamination							-
Number and size of particles and fibers in 100-ml fluid							SAE Method ARP-198
25-100 micrometers							-
100-500 micrometers							-
over 500 micrometers							-
particles over 250 micrometers except fibers (length ten times diameter)							-
Gravimetric Value, mg/100 ml							SAE Method ARP-198
specific gravity at 70/60 °F	0.858						ASTM D-1298
Color							ASTM D-1500
Cost \$/gal							-
Availability							-
Available from supplier proprietary							

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Fluid Code D

Suggested Uses and Possible Limitations

Fluid Code D has been suggested for use in a friction drive system. Its relatively high viscosity and lack of corrosion inhibition make it questionable for use as a general petroleum lubricant or hydraulic fluid. Its dielectric properties have not been determined. It is flammable.

Fluid Code D(1)  
(Petroleum Base Fluid)

				Method
				See New Departure Letter to NSRDC, 26 Feb 1968
<u>Viscometric Properties</u>				
Viscosity, centistokes, at:				
0 psig	19.7			
3,000 psig	-			
5,000 psig	53.2			
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
Viscosity, centistokes, at 100° F.	15.7			
Viscosity, centistokes, at 210° F.	3.86			
0 psig				ASTM D-445
Viscosity Slope, ASTM	0.776			-
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:				Fed. Method 6503 (modified)
1 kg				-
3 kg				-
5 kg				-
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	- 50.1			-
Stainless Steel, 316	+ 0.6			-
Copper-Nickel (70-30)	- 0.7			-
Aluminum, QQ-A-250-4b	-133.5			-
Phosphor-Bronze	- 70.7			-
Steel, galvanized	-290.5			-
Steel, 1009	-828.6			-
Aluminum, QQ-A-250-11	- 25.8			-
Bronze	- 33.1			-
Monel	+ 0.5			-
Silver Base Brazing Alloy	- 2.5			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

					Method
<u>Corrosion Protection (Cont)</u> Electrically Coupled Specimens: Copper-Aluminum, QQ-A-250-11 Aluminum QQ-A-250-4b - Copper-Nickel (70-30) Monel-Bronze Stainless Steel (316) - Phosphor-Bronze Silver Base Brazing Alloy - Steel, 1004 Aluminum QQ-A-250-11 - Bronze Aluminum QQ-A-250-4b - Steel, 1009 20,000 PSIG Stirred Corrosion Test, weight change, mg					See Chapter 2 Test C-4
Insulated Specimens: Copper Stainless Steel, 316 Copper-Nickel (70-30) Aluminum, QQ-A-250-4b Phosphor-Bronze Steel, galvanized Steel, 1009 Aluminum, QQ-A-250-11 Bronze Monel Silver Base Brazing Alloy Electrically Coupled Specimens: Copper-Aluminum, QQ-A-250-11 Aluminum, QQ-A-250-4b - Copper-Nickel (70-30) Monel-Bronze Stainless Steel (316) - Phosphor-Bronze Silver Base Brazing Alloy - Steel, 1009 Aluminum, QQ-A-250-11 - Bronze Aluminum, QQ-A-250-4b - Steel, 1009					
Pump Test Average Weight Loss, mg Steel Gears Bronze Bushings Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup> Copper Aluminum Steel, galvanized Steel, 1009 Silver Base Brazing Alloy					Proposed military specification for sea-water emulsi- fying oils
<u>Dielectric Properties</u> Resistivity, °F, ohm-cm: As-Received With Sea-Water Contamination: 0.1% by volume 0.5% by volume 2.0% by volume With Carbon Contamination: 0.1% wt/vol. 0.25% wt/vol. 0.5% wt/vol.					ASTM D-1169 (mod- ified). See Chap- ter 2 Test E-1 Chapter 2 Test E-5 - - Chapter 2 Test E-6 -

				Method
<u>Dielectric Properties (Cont.)</u>				See Chapter 2 Test E-7
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				See Chapter 1 Test E-7
Dissipation Factor, °F, %				See Chapter 2 Test E-7
As-Received				-
With Sea-Water Contamination:				-
0.1% by volume				-
0.5% by volume				-
2.0% by volume				-
With Carbon Contamination:				See Chapter 2 Test E-6
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				-
Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv				ASTM D-877 (modified). See Chapter 2, Test E-5
As received				See Chapter 2 Test E-5
With sea-water contamination:				-
0.1% by volume				-
0.5% by volume				-
2.0% by volume				-
With carbon contamination:				See Chapter 2 Test E-6
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				See Chapter 2 Test E-8
Number of tests				-
Operations to failure (range)				-
<u>Emulsion Stability</u>				ASTM D-1401
Paddle Test, after 1-hour set- tling:				-
Oil, ml	40			-
Emulsion, ml	0			-
Water, ml	40			-
Electric Probe Test, time for water separation, min				See Chapter 2 Test E-4
<u>Material Compatibility</u> Static 20KPSI				See Chapter 2 Test C-3
Butyl				-
Buna N				-
Viton B				-
Ethylene-Propylene				-
Tetrafluoroethylene (Teflon)				-
Neoprene				-
Thiokol				-
Silicone				-
Fluorosilicone				-

Volatility		Petroleum			Method
Toxicity		55° F	100° F	150° F	-
Density, grams/cubic centimeter, atm					See NSRDL Annapolis Report MATLAB 510
0 psig					
4,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
Isothermal Compressibility, volume decrease, %, atm		55° F	100° F	150° F	See NSRDL Annapolis Report MATLAB 510
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
Chemical Stability					ASTM D-282
Oxidation Stability Test, 203° F, hours to failure					Fed. Method 520H
Oxidation Stability Test, 250° F					Military specification MIL-H-19457B
Hydrolytic Stability Test					-
Specimen change, mg					-
Specimen appearance					-
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
Fire Resistance					ASTM D-282
Flash Point, °F		270			ASTM D-282
Fire Point, °F		295			ASTM D-2155
Autogeneous Ignition Temperature, °F					See MIL Report 51/66 of March 1967
High-Pressure Spray Combustor					-
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
Miscellaneous Properties					ASTM D-97
Pour Point, °F		-60			ASTM D-892
Foaming Tendency, 75° F		-			-
Foam after 5-minute aeration, ml					-
Time out, minutes		<1			-
Foam after 10-minute settling, ml		0			-
Neutralization Number, mg KOH/gram		0.01			ASTM D-974
Water Content, % by weight		0.010			ASTM D-1744
Neutrality, qualitative		neutral			Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Specific gravity at 60/60 °F		0.837			ASTM D-1298
Color					ASTM D-1500
Cost \$/gal			Available from supplier		-
Availability			proprietary		-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Fluid Code E

Suggested Uses and Possible Limitations

Fluid Code E is used in submersible motors. There is considerable field experience to show that this fluid may be used as a motor immersion fluid. Its viscosity is low, it provides no corrosion protection, and it is extremely flammable. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

Fluid Code z(1)  
(Petroleum Base Fluid)

				Method
Viscometric Properties	50° F	100° F	150° F	
Viscosity, centistokes, at:				
0 psig				
3,000 psig				See NSRDL
5,000 psig				Annapolis Report
8,000 psig				MATLAB '90
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100 °F,	4.26			
Viscosity, centistokes, at 210° F,	1.50			ASTM D-446
0 psig				
Viscosity Slope, ASTM	0.839			
<b>Lubricating Ability</b>				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				Fed. Method 6.02 (modified)
1 kg				-
3 kg				-
5 kg				-
<b>Corrosion Protection</b>				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	- 74.2			-
Stainless Steel, 316	+ 1.2			-
Copper-Nickel (70-30)	+ 0.7			-
Aluminum, QQ-A-250-4b	-456.5			-
Phosphor-Bronze	- 25.9			-
Steel, galvanized	-1227.4			-
Steel, 1009	-1598.2			-
Aluminum, QQ-A-250-11	+ 159.7			-
Bronze	- 46.7			-
Monel	+ 0.1			-
Silver Base Brazing Alloy	- 17.3			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

				Method
Corrosion Protection (cont)				
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-K-210-11				
Aluminum, QQ-A-250-4b -				
Copper-Nickel (70-30)				
Monel-Bronze				
Stainless Steel (316) -				
Phosphor-Bronze				
Silver Base Braze Alloy -				
Steel, 1009				
Aluminum, QQ-A-250-11 -				
Bronze				
Aluminum, QQ-A-250-4b -				
Steel, 1009				
20,000 PSI'd Steel Corrosion				
Test, weight change, mg				
Insulated Specimens (4)				
Copper				
Stainless Steel, 316				
Copper-Nickel (70-30)				
Aluminum, QQ-A-250-4b				
Phosphor-Bronze				
Steel, galvanized				
Steel, 1009				
Aluminum, QQ-A-250-11				
Bronze				
Monel				
Silver Base Braze Alloy				
Electrically Coupled Specimens:				
Copper-Aluminum, QQ-A-250-11				
Aluminum, QQ-A-250-4b -				
Copper-Nickel (70-30)				
Monel-Bronze				
Stainless Steel (316) -				
Phosphor-Bronze				
Silver Base Braze Alloy -				
Steel, 1009				
Aluminum, QQ-A-250-11 -				
Bronze				
Aluminum, QQ-A-250-4b -				
Steel, 1009				
Pump Test				
Average Weight Loss, mg				
Steel Gears				
Bronze Bushings				
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>				
Copper				
Aluminum				
Steel, galvanized				
Steel, 1009				
Silver Base Braze Alloy				
Dielectric Properties				
Resistivity, 73 °F, ohm-cm:				
As-Received	2.6x10 <sup>13</sup>			
With Sea-Water Contamination:				
0.1% by volume				
0.5% by volume				
2.0% by volume				
With Carbon Contamination:				
0.1% wt/vol.				
0.25% wt/vol.				
0.5% wt/vol.				

				Method
<u>Dielectric Properties (cont)</u>				See Chapter 2 Test E-7
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				See Chapter 2 Test E-1
Dissipation Factor, 75 °F, %	0.8			See Chapter 2 Test E-2
As received				-
With sea-water contamination:				-
0.1% by volume				-
0.5% by volume				-
2.0% by volume				-
With carbon contamination:				See Chapter 2 Test E-6
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				-
Dielectric Breakdown Voltage, 0.05-inch gap, 73 °F, kv	27.2			ASTM D-877 (modified). See Chapter 2. Test E-3
As received				See Chapter 2 Test E-5
With sea-water contamination:				-
0.1% by volume				-
0.5% by volume				-
2.0% by volume				-
With carbon contamination:				See Chapter 2 Test E-6
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				See Chapter 2 Test E-3
Number of tests				-
Operations to failure (range)				-
<u>Emulsion Stability</u>				
Paddle Test, after 1-hour set- tling:				ASTM D-1401
Oil, ml	40			-
Emulsion, ml	0			-
Water, ml	40			-
Electric Probe Test, time for water separation, min				See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>				See Chapter 2 Test C-3
Butyl				-
Buna N				-
Viton B				-
Ethylene-Propylene				-
Tetrafluoroethylene (Teflon)				-
Neoprene				-
Thiokol				-
Silicone				-
Fluorosilicone				-

					Method
		Petroleum	100° F	150° F	
<u>Volatility</u>					-
<u>Toxicity</u>					-
<u>Density, grams/cubic centimeter, at:</u>	35° F		100° F	150° F	
0 psig					See NSRDL Annapolis Report NATLAB 550
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, at:</u>	75° F		100° F	150° F	
0 psig					See NSRDL Annapolis Report NATLAB 550
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					
Hydrolytic Stability Test					Fed. Method 5308
Specimen change, mg					Military specification MIL-H-19457B
Specimen appearance					-
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
<u>Fire Resistance</u>					
Flash Point, °F	185				ASTM D-92
Fire Point, °F	190				ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combuster					See MEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Pour Point, °F					ASTM D-97
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-974
Water Content, % by weight					ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Specific gravity at 69/60 °F	0.830				ASTM D-1298
Color					ASTM D-1500
Cost \$/gal		Available from supplier			-
Availability		Proprietary			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Fluid Code F

Suggested Uses and Possible Limitations

Fluid Code F has a low atmospheric pressure viscosity for a general-purpose petroleum lubricant over a sustained time period. Its corrosion-inhibiting properties are moderately good for both ferrous and nonferrous metals. It is flammable. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

Fluid Code  $\gamma(1)$   
(Petroleum Base Fluid)

				Method
	50° F	100° F	140° F	
<u>Viscometric Properties</u>				
Viscosity, centistokes, at:				
0 psig				See NSRDI
3,000 psig				Annapolis Report
5,000 psig				M'TLAB
5,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F,	4.68			ASTM D-244
Viscosity, centistokes, at 210° F,	1.39			
0 psig				-
Viscosity Slope, ASTM	0.836			-
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				Ref. Method C-10 (modified)
1 kg				-
3 kg				-
5 kg				-
<u>Corrosion Protection</u>				
Stirred Kust Test, 10% seawater, 140° F, 2 days	Pass			ASTM D-661
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 1 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 1 Test C-1
Copper	- 0.5			-
Stainless Steel, 316	- 0.2			-
Copper-Nickel (70-30)	- 0.4			-
Aluminum, QQ-A-250-4b	- 0.2			-
Phosphor-Bronze	- 0.4			-
Steel, galvanized	- 8.0			-
Steel, 1009	- 0.2			-
Aluminum, QQ-A-250-11	- 0.2			-
Bronze	- 0.7			-
Monel	- 0.3			-
Silver Base Brazing Alloy	- 0.2			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 1 Test C-7
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

					Method
<u>Corrosion Protection (Cont.)</u>					
Electrically Coupled Specimens:					-
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Brazing Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 PSIG Stirred Corrosion					See Chapter 2
Test, weight change, mg				Test C-4	
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Brazing Alloy					-
Electrically Coupled Specimens:					-
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Brazing Alloy -					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
Pump Test					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					Proposed military specification for sea-water emulsifying oils
each, mg/cm <sup>2</sup>					
Copper					-
Aluminum					-
Steel, galvanized					-
Steel, 1009					-
Silver Base Brazing Alloy					-
<u>Dielectric Properties</u>					
Resistivity, 75 °F, ohm-cm:					
As-Received					
With Sea-Water Contamination:					ASTM D-1169 (modified). See Chapter 2, Test E-1
0.1% by volume					Chapter 2
0.5% by volume					Test E-5
2.0% by volume					-
With Carbon Contamination:					Chapter 2
0.1% wt/vol.					Test E-6
0.25% wt/vol.					-
0.5% wt/vol.					-

		Method			
<u>Dielectric Properties (Cont)</u>					
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					See Chapter 2 Test E-7
Not filtered					-
Filtered					-
Solids generated, gram					-
Dissipation Factor, 75 °F, %					See Chapter 2 Test E-2
As-Received					See Chapter 2 Test E-5
With Sea-Water Contamination:					-
0.1% by volume					-
0.5% by volume					See Chapter 2 Test E-6
2.0% by volume					-
With Carbon Contamination:					-
0.10% wt/vol.					-
0.25% wt/vol.					ASTM D-877 (mod- ified). See Chap- ter 2. Test E-3
0.50% wt/vol.					Chapter 2 - Test E-5
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					-
Not filtered					-
Filtered					-
Solids generated, gram					-
Dielectric Breakdown Voltage, 0.05-inch gap, 75 °F, kv					-
As received	24.6				-
With sea-water contamination:					See Chapter 2 Test E-6
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With carbon contamination:					-
0.10% wt/vol.					-
0.25% wt/vol.					See Chapter 2 Test E-8
0.50% wt/vol.					-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load					-
Not filtered					-
Filtered					-
Solids generated, gram					-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F					See Chapter 2 Test E-8
Number of tests					-
Operations to failure (range)					-
<u>Emulsion Stability</u>					ASTM D-1401
Paddle Test, after 1-hour set- tling:					-
Oil, ml	40				-
Emulsion, ml	8				-
Water, ml	32				-
Electric Probe Test, time for water separation, min					See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>					See Chapter 2 Test C-3
Butyl					-
Buna N					-
Viton B					-
Ethylene-Propylene					-
Tetrafluoroethylene (Teflon)					-
Neoprene					-
Thiokol					-
Silicone					-
Fluorosilicone					-

Properties of Petroleum				Spec. No. 1	
Property	Test Method	120° F	100° F	10° F	Spec. No. 2
<u>Volatility</u>		Petroleum			
Boiling Point, °F		120° F	100° F	10° F	
Density, grams/cubic centimeter, at:					
0 psig					Spec. No. 1
4,000 psig					ASTM D-1
6,000 psig					ASTM D-1
8,000 psig					ASTM D-1
10,000 psig					ASTM D-1
12,000 psig					ASTM D-1
14,000 psig					ASTM D-1
16,000 psig					ASTM D-1
18,000 psig					ASTM D-1
20,000 psig					ASTM D-1
Isothermal Correlation, % Volume decrease, % at:		120° F	100° F	10° F	
0 psig					Spec. No. 1
4,000 psig					ASTM D-1
6,000 psig					ASTM D-1
8,000 psig					ASTM D-1
10,000 psig					ASTM D-1
12,000 psig					ASTM D-1
14,000 psig					ASTM D-1
16,000 psig					ASTM D-1
18,000 psig					ASTM D-1
20,000 psig					ASTM D-1
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure	1000+				ASTM D-247
Oxidation Stability Test, 250° F					
Hydrolytic Stability Test					
Specimen change, mg					Fed. Method 5101
Specimen appearance					Military specification MIL-H-1457B
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles,					-
Thermal Stability Test					-
<u>Fire Resistance</u>					
Flash Point, °F	180				ASTM D-93
Fire Point, °F	300				ASTM D-282
Autogenous Ignition Temperature, °F					ASTM D-2195
High-Pressure Spray Combustor					See MIL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Pour Point, °F					ASTM D-25
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-274
Water Content, % by weight	0.016				ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Turbimetric Value, mg/100 ml					SAE Method ARP-785
Specific gravity at 71/60 °F	0.832				ASTM D-1298
Color					ASTM D-1500
Cost, \$/gal		Available from supplier			-
Availability		Proprietary			-

<sup>1</sup> Determinations made at atmospheric pressure, unless noted.

Fluid Code G

Suggested Uses and Possible Limitations

The atmospheric pressure viscosity of Fluid Code G suggests that it could be a general-purpose petroleum fluid. Its corrosion-inhibiting properties are moderately good for both ferrous and nonferrous metals. Initial dielectric properties are good, but additional information relating to electrical applications is lacking.

**Fluid Code G(1)**  
(Petroleum Base Fluid)

Viscometric Properties	50° F	100° F	150° F	Method	
				100° F	150° F
Viscosity, centistokes, at:					
0 psig					
5,000 psig					
9,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
Viscosity, centistokes, at 100° F.	10.80				
Viscosity, centistokes, at 210° F.	2.50				
0 psig					
Viscosity Slope, ASTM	0.823				
Lubricating Ability					
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:					
1 kg					
3 kg					
5 kg					
Corrosion Protection					
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass				
On-Off Rust Test, 50% seawater, 140° F, 20 days	Fail				
Ambient Pressure, coupon stirred, corrosion test, weight change, mg					
Copper	-0.1				
Stainless Steel, 316	+0.2				
Copper-Nickel (70-30)	-0.1				
Aluminum, QQ-A-250-4b	+0.2				
Phosphor-Bronze	0				
Steel, galvanized	-6.6				
Steel, 1009	+0.5				
Aluminum, QQ-A-250-11	+0.2				
Bronze	-0.3				
Monel	+0.1				
Silver Base Brazing Alloy	-0.7				
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg					
Insulated Specimens:					
Copper					
Stainless Steel, 316					
Copper-Nickel (70-30)					
Aluminum, QQ-A-250-4b					
Phosphor-Bronze					
Steel, galvanized					
Steel, 1009					
Aluminum, QQ-A-250-11					
Bronze					
Monel					
Silver Base Brazing Alloy					

				Method	
<u>Corrosion Protection (Cont)</u>					
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11				-	
Aluminum QQ-A-250-4b -				-	
Copper-Nickel (70-30)				-	
Monel-Bronze				-	
Stainless Steel (316) -				-	
Phosphor-Bronze				-	
Silver Base Brazing Alloy -				-	
Steel, 1004				-	
Aluminum QQ-A-250-11 -				-	
Bronze				-	
Aluminum QQ-A-250-4b -				-	
Steel, 1009				-	
20,000 PSIG Stirred Corrosion Test, weight change, mg	(10% seawater)			See Chapter 2 Test C-4	
<u>Insulated Specimens:</u>					
Copper	-0.5			-	
Stainless Steel, 316	0			-	
Copper-Nickel (70-30)	0			-	
Aluminum, QQ-A-250-4b	-0.1			-	
Phosphor-Bronze	-0.1			-	
Steel, galvanized	-0.3			-	
Steel, 1009	0			-	
Aluminum, QQ-A-250-11	0			-	
Bronze	+0.1			-	
Monel	0			-	
Silver Base Brazing Alloy	-0.6			-	
<u>Electrically Coupled Specimens:</u>					
Copper-Aluminum, QQ-A-250-11	-1.3	-0.3		-	
Aluminum, QQ-A-250-4b -				-	
Copper-Nickel (70-30)	-0.3	-0.1		-	
Monel-Bronze	0	+0.3		-	
Stainless Steel (316) -				-	
Phosphor-Bronze	0	-0.1		-	
Silver Base Brazing Alloy -				-	
Steel, 1009	-0.6	-0.3		-	
Aluminum, QQ-A-250-11 -				-	
Bronze	-0.1	+0.3		-	
Aluminum, QQ-A-250-4b -				-	
Steel, 1009	-0.1	0		-	
<u>Pump Test</u>					
Average Weight Loss, mg					
Steel Gears	1				
Bronze Bushings	8				
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>	-				
Copper	0.01			-	
Aluminum	0.03			-	
Steel, galvanized	0.01			-	
Steel, 1009	0.01			-	
Silver Base Brazing Alloy	0.02			-	
<u>Dielectric Properties</u>					
Resistivity, 75 °F ohm-cm:	8.0x10 <sup>13</sup>				
As-Received					
With Sea-Water Contamination:					
0.1% by volume					
0.5% by volume					
2.0% by volume					
With Carbon Contamination:					
0.1% wt/vol.					
0.25% wt/vol.					
0.5% wt/vol.					

		Method				
<u>Dielectric Properties (Cont)</u>		See Chapter 2 Test E-7				
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-				
Not filtered		-				
Filtered		-				
Solids generated, gram		See Chapter 2 Test E-2				
Dissipation Factor, 75 °F, %		See Chapter 2 Test E-5				
As-Received		-				
With Sea-Water Contamination:		-				
0.1% by volume		-				
0.5% by volume		-				
2.0% by volume		-				
With Carbon Contamination:		See Chapter 2 Test E-6				
0.10% wt/vol.		-				
0.25% wt/vol.		-				
0.50% wt/vol.		-				
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-				
Not filtered		-				
Filtered		-				
Solids generated, gram		-				
Dielectric Breakdown Voltage, 0.05-inch gap, 75 °F, kv		ASTM D-877 (mod- ified). See Chap- ter 2, Test E-3				
As received		See Chapter 2 Test E-5				
With sea-water contamination:		-				
0.1% by volume		-				
0.5% by volume		-				
2.0% by volume		-				
With carbon contamination:		See Chapter 2 Test E-6				
0.10% wt/vol.		-				
0.25% wt/vol.		-				
0.50% wt/vol.		-				
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load		-				
Not filtered		-				
Filtered		-				
Solids generated, gram		-				
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65-85° F		See Chapter 2 Test E-3				
Number of tests		-				
Operations to failure (range)		-				
<u>Emulsion Stability</u>		ASTM D-1401				
Paddle Test, after 1-hour set- tling:		-				
Oil, ml		-				
Emulsion, ml		-				
Water, ml		-				
Electric Probe Test, time for water separation, min		See Chapter 2 Test E-4				
<u>Material Compatibility Static 20KPSI</u>		See Chapter 2 Test C-3				
Butyl		-				
Buna N		-				
Viton B		-				
Ethylene-Propylene		-				
Tetrafluoroethylene (Teflon)		-				
Neoprene		-				
Thiokol		-				
Silicone		-				
Fluorosilicone		-				

				Method
<u>Volatility</u>				
<u>Toxicity</u>	Petroleum			
<u>Density, grams/cubic centimeter, atm</u>	35° F	100° F	150° F	
0 psig				
5,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Isothermal Compressibility, volume decrease, %, at:</u>	35° F	100° F	150° F	
0 psig				
5,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Chemical Stability</u>				
<u>Oxidation Stability Test, 203° F, hours to failure</u>	1000+			ASTM D-947
<u>Oxidation Stability Test, 250° F</u>				Fed. Method 1707
<u>Hydrolytic Stability Test</u>				Military Specification MIL-H-19457B
Specimen change, mg				-
Specimen appearance				-
Fluid acid number increase, mg KOH/gram fluid				-
Water acidity, mg KOH				-
Insolubles, %				-
<u>Thermal Stability Test</u>				-
<u>Fire Resistance</u>				
Flash Point, °F	300			ASTM D-32
Fire Point, °F	325			ASTM D-28
<u>Autogeneous Ignition Temperature, °F</u>				ASTM D-4155
<u>High-Pressure Spray Combustor</u>				See NEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F				-
Minimum reaction temperature, °F				-
No indication of fire, °F				-
Maximum pressure change, psi				-
Lowest temperature of maximum pressure change, °F				-
Temperature range explored, °F				-
<u>Miscellaneous Properties</u>				
Pour Point, °F	<45			ASTM D-97
Foaming Tendency, 75° F				ASTM D-892
Foam after 5-minute aeration, ml				-
Time out, minutes				-
Foam after 10-minute settling, ml				-
Neutralization Number, mg KOH/gram	0.10			ASTM D-774
Water Content, % by weight	0.005			ASTM D-1744
Neutrality, qualitative				Fed. Method 1101
Contamination				-
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP-598
25-100 micrometers				-
100-500 micrometers				-
over 500 micrometers				-
particles over 250 micrometers except fibers (length ten times diameter)				-
Gravimetric Value, mg/100 ml	0.872			SAE Method ARP-785
Specific Gravity at 70/60 °F				ASTM D-1298
Color	available from supplier			ASTM D-1708
Cost \$/gal	proprietary			-
Availability				-

Determinations made at atmospheric pressure, unless noted.

Fluid Code H

Suggested Uses and Possible Limitations

The atmospheric pressure viscosity of Fluid Code H would lead to the prediction that it would not be suitable for hydraulic systems or lubrication uses at more than 4000-foot depth. properties are moderately good for both ferrous and nonferrous metals.

Fluid Code H<sup>(1)</sup>  
(Petroleum Base Fluid)

Viscometric Properties	35° F	100° F	170° F	Method
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
5,000 psig				MATLAB <sup>TM</sup>
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F,	34.0			
Viscosity, centistokes, at 210° F,	5.31			ASTM D-446
0 psig				-
Viscosity Slope, ASTM	0.764			-
Lubricating Ability				Fed. Method F-77 (modified)
4-Ball Wear Test, 30 min, 50° C, 52100 steel, average scar dia., mm:				-
1 kg				-
3 kg				-
5 kg				-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	+2.0			-
Stainless Steel, 316	+0.1			-
Copper-Nickel (70-30)	+0.1			-
Aluminum, QQ-A-250-4b	+0.3			-
Phosphor-Bronze	+0.2			-
Steel, galvanized	-0.9			-
Steel, 1009	+0.5			-
Aluminum, QQ-A-250-11	+0.3			-
Bronze	+0.2			-
Monel	+0.1			-
Silver Base Braze Alloy	-0.3			
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Braze Alloy				-

					Method
<u>Corrosion Protection (Cont)</u>					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 PSIG Stirred Corrosion					See Chapter 2
Test, weight change, mg					Test C-4
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Braze Alloy					-
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
Pump Test					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss,					
each, mg/cm <sup>2</sup>					
Copper					-
Aluminum					-
Steel, galvanized					-
Steel, 1009					-
Silver Base Braze Alloy					-
<u>Dielectric Properties</u>					
Resistivity, °F, ohm-cm:					
As-Received					
With Sea-Water Contamination:					
0.1% by volume					ASTM D-1169 (modified). See Chapter 2. Test E-1
0.5% by volume					Chapter 2
2.0% by volume					Test E-5
With Carbon Contamination:					-
0.1% wt/vol.					Chapter 2
0.25% wt/vol.					Test E-6
0.5% wt/vol.					-

<u>Dielectric Properties (Cont.)</u>		Method			
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram				See Chapter 2 Test E-7
Dissipation Factor, °F. %	As-Received				-
With Sea-Water Contamination:	0.1% by volume				-
	0.5% by volume				-
	2.0% by volume				-
With Carbon Contamination:	0.10% wt/vol.				See Chapter 2 Test E-5
	0.25% wt/vol.				-
	0.50% wt/vol.				-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram				See Chapter 2 Test E-6
Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv	As received				-
With sea-water contamination:	0.1% by volume				-
	0.5% by volume				-
	2.0% by volume				-
With carbon contamination:	0.10% wt/vol.				ASTM D-877 (modified). See Chapter 2 Test E-5
	0.25% wt/vol.				-
	0.50% wt/vol.				-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load	Not filtered Filtered Solids generated, gram				See Chapter 2 Test E-6
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F	Number of tests				-
Operations to failure (range)					-
<u>Emulsion Stability</u>					
Paddle Test, after 1-hour settling:					ASTM D-1401
Oil, ml	40				-
Emulsion, ml	0				-
Water, ml	40				-
Electric Probe Test, time for water separation, min					See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>					See Chapter 2 Test C-3
Butyl					-
Buna N					-
Viton B					-
Ethylene-Propylene					-
Tetrafluoroethylene (Teflon)					-
Neoprene					-
Thiokol					-
Silicone					-
Fluorosilicone					-

<u>Volatility</u>		<u>Petroleum</u>				<u>Method</u>
<u>Toxicity</u>			70° F	100° F	150° F	
<u>Density, grams/cubic centimeter, at:</u>						
0 psig						
3,000 psig						
5,000 psig						
8,000 psig						
10,000 psig						
15,000 psig						
20,000 psig						
<u>Isothermal Compressibility, volume decrease, %, at:</u>						
0 psig						
3,000 psig						
5,000 psig						
8,000 psig						
10,000 psig						
15,000 psig						
20,000 psig						
<u>Chemical Stability</u>						
Oxidation Stability Test, 203° F, hours to failure						ASTM D-913
Oxidation Stability Test, 250° F						Fed. Method 5308
Hydrolytic Stability Test						Military specification MIL-H-19457B
Specimen change, mg						-
Specimen appearance						-
Fluid acid number increase, mg KOH/gram fluid						-
Water acidity, mg KOH						-
Insolubles, %						-
Thermal Stability Test						-
<u>Fire Resistance</u>						
Flash Point, °F		395				ASTM D-92
Fire Point, °F		445				ASTM D-92
Autogenous Ignition Temperature, °F						ASTM D-2155
High-Pressure Spray Combustor						See MEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F						-
Minimum reaction temperature, °F						-
No indication of fire, °F						-
Maximum pressure change, psi						-
Lowest temperature of maximum pressure change, °F						-
Temperature range explored, °F						-
<u>Miscellaneous Properties</u>						
Pour Point, °F						ASTM D-97
Foaming Tendency, 75° F						ASTM D-892
Foam after 5-minute aeration, ml						-
Time out, minutes						-
Foam after 10-minute settling, ml						-
Neutralization Number, mg KOH/gram						ASTM D-974
Water Content, % by weight		0.002				ASTM D-1744
Neutrality, qualitative						Fed. Method 5101
Contamination						-
Number and size of particles and fibers in 100-ml fluid						SAE Method ARP-598
25-100 micrometers						-
100-500 micrometers						-
over 500 micrometers						-
particles over 250 micrometers except fibers (length ten times diameter)						-
Gravimetric value, mg/100 ml						SAE Method ARP-785
Specific gravity at 70/60 °F		0.866				ASTM-D-1298
Color						ASTM D-1500
Cost \$/gal			available from supplier			-
Availability			proprietary			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Fluid Code J

Suggested Uses and Possible Limitations

Fluid Code J, a petroleum oil product, meets the requirements of the United States Pharmacopelia (USP) for medicinal mineral oils. It has been used in a deep submergence vehicle as an immersion fluid for nonmoving electrical parts. Field experience has shown that it has failed as a lubricant for electric motors and gears at 1000 psig. It provides no corrosion protection. It has satisfactory dielectric properties. Its poor sea-water emulsion stability makes it questionable for use with motors at deep submergence pressures. Although its dielectric properties are good, its relatively high viscosity makes it a questionable choice for other electrical applications at deep submergence pressures.

Fluid Code J(1)  
(Petroleum Base Fluid)

				Method
<u>Viscometric Properties</u>				
Viscosity, centistokes, at:	55° F	100° F	210° F	
0 psig				
3,000 psig				See NSRDL
5,000 psig				Annapolis Report
8,000 psig				MATLAB 550
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F.	44.1			
Viscosity, centistokes, at 210° F.	6.08			ASTM D-445
0 psig				-
Viscosity Slope, ASTM	0.771			
<u>Lubricating Ability</u>				
4-Ball Wear Test, 30 min, 50° C.				Fed. Method 6503
52100 steel, average scar dia.,				(modified)
mm:				
1 kg				-
3 kg				-
5 kg				-
<u>Corrosion Protection</u>				
Stirred Rust Test, 10% seawater,				ASTM D-665
140° F, 2 days				
On-Off Rust Test, 50% seawater,				See Chapter 2
140° F, 30 days				Test C-5
Ambient Pressure, coupon				See Chapter 2
stirred, corrosion test, weight				Test C-1
change, mg				-
Copper	- 8.5			-
Stainless Steel, 316	+ 2.7			-
Copper-Nickel (70-30)	+ 1.3			-
Aluminum, QQ-A-250-4b	+552.1			-
Phosphor-Bronze	- 12.7			-
Steel, galvanized	+ 62.9			-
Steel, 1009	-909.7			-
Aluminum, QQ-A-250-11	+134.9			-
Bronze	- 10.0			-
Monel	- 2.4			-
Silver Base Brazing Alloy	+ 2.5			-
20,000 PSIg Pressure-Cycled				See Chapter 2
Corrosion Test (1% seawater),				Test C-2
weight change, mg				-
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

					Method
<u>Corrosion Isolation (Cont)</u>					
Electrically Coupled Specimens:					-
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 PSIG Stirred Corrosion					See Chapter 2
Test, weight change, mg					Test C-4
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Braze Alloy					-
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Braze Alloy -					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
Pump Test					Proposed military specification for sea-water emulsifying oils
Average Weight Loss, mg					
Steel Gears					-
Bronze Bushings					-
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					-
Copper					-
Aluminum					-
Steel, galvanized					-
Steel, 1009					-
Silver Base Braze Alloy					-
Dielectric Properties					ASTM D-1169 (modified). See Chapter 2 Test E-1
Resistivity, 80 °F, ohm-cm:					Chapter 2 Test E-5
As-Received					-
With Sea-Water Contamination:	(2)				-
0.5% by volume					Chapter 2 Test E-6
2.0% by volume					-
With Carbon Contamination:					-
0.25% wt/vol.					-
0.5% wt/vol.					-

Dielectric Properties (Cont.)				Method	
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				See Chapter 2 Test E-7	
Not filtered	$5.4 \times 10^{14}$			-	
Filtered	$2.2 \times 10^{14}$			-	
Solids generated, gram	1.16			-	
Dissipation Factor, 80 °F, %				See Chapter 2 Test E-2	
As-Received	0.0			See Chapter 2 - Test E-5	
With Sea-Water Contamination:	0.0			-	
0.1% by volume				See Chapter 2 Test E-6	
0.5% by volume				-	
2.0% by volume				-	
With Carbon Contamination:				See Chapter 2 Test E-6	
0.10% wt/vol.				-	
0.25% wt/vol.				-	
0.50% wt/vol.				-	
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				ASTM D-877 (modified). See Chapter 2. Test E-3	
Not filtered	0.9			See Chapter 2 Test E-5	
Filtered	0.6			-	
Solids generated, gram				-	
Dielectric Breakdown Voltage, 0.05-inch gap, 80 °F, kv				See Chapter 2 Test E-6	
As received	27.6			-	
With sea-water contamination:	9.0			-	
0.1% by volume				-	
0.5% by volume				-	
2.0% by volume				-	
With carbon contamination:				See Chapter 2 Test E-6	
0.10% wt/vol.				-	
0.25% wt/vol.				-	
0.50% wt/vol.				-	
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-	
Not filtered	7.2			-	
Filtered	28.6			-	
Solids generated, gram				-	
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				See Chapter 2 Test E-8	
Number of tests				-	
Operations to failure (range)				-	
Emulsion Stability				ASTM D-1401	
Puddle Test, after 1-hour settling:				-	
Oil, ml	40			-	
Emulsion, ml	0			-	
Water, ml	40			-	
Electric Probe Test, time for water separation, min	0.2			See Chapter 2 Test E-4	
Material Compatibility Static 20KPSI				See Chapter 2 Test C-3	
Butyl				-	
Buna N				-	
Viton B				-	
Ethylene-Propylene				-	
Tetrafluoroethylene (Teflon)				-	
Neoprene				-	
Thiokol				-	
Silicone				-	
Fluorosilicone				-	

				Method
<u>Volatility</u>				-
<u>Toxicity</u>				-
<u>Density</u> , grams/cubic centimeter, at:	Petroleum	35° F	100° F	150° F
0 psig				
3,000 psig				
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Isothermal Compressibility</u> , volume decrease, % at:		35° F	100° F	150° F
0 psig				
3,000 psig				
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Chemical Stability</u>				
Oxidation Stability Test, 203° F, hours to failure				ASTM D-943
Oxidation Stability Test, 250° F				Fed. Method 5308
Hydrolytic Stability Test				Military specification MIL-H-1945B
Specimen change, mg		0.12		-
Specimen appearance		Satisfactory		-
Fluid acid number increase, mg KOH/gram fluid		0		-
Water acidity, mg KOH		0.31		-
Insolubles, %		nil		-
Thermal Stability Test				-
<u>Fire Resistance</u>				
Flash Point, °F	400			ASTM D-92
Fire Point, °F	435			ASTM D-92
Autogeneous Ignition Temperature, °F				ASTM D-2155
High-Pressure Spray Combustor				See MEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F				-
Minimum reaction temperature, °F				-
No indication of fire, °F				-
Maximum pressure change, psi				-
Lowest temperature of maximum pressure change, °F				-
Temperature range explored, °F				-
<u>Miscellaneous Properties</u>				
Pour Point, °F	-5			ASTM D-97
Foaming Tendency, 75° F				ASTM D-892
Foam after 5-minute aeration, ml				-
Time out, minutes				-
Foam after 10-minute settling, ml				-
Neutralization Number, mg KOH/gram	0.03			ASTM D-974
Water Content, % by weight	0.005			ASTM D-1744
Neutrality, qualitative				Fed. Method 5101
Contamination				-
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP-598
25-100 micrometers				-
100-500 micrometers				-
over 500 micrometers				-
particles over 250 micrometers except fibers (length ten times diameter)				-
Gravimetric Value, mg/100 ml	0.868			SAE Method ARP-785
Specific gravity at 69/60 °F				ASTM D-1298
Color				ASTM D-1500
Cost \$/gal		available from supplier		-
Availability		proprietary		-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted. <sup>2</sup>Saturated with seawater.

Fluid Code K

Suggested Uses and Possible Limitations

Fluid Code K meets the requirements of the National Formulary (NF) for medicinal mineral oils. As a petroleum oil product its dielectric properties have not been determined. It has been used as an immersion fluid for nonmoving electric components at depths not exceeding 2000 feet. In one particular instance in the field, it failed as a lubricant for moving parts. It provides no corrosion protection.

Fluid Code K<sup>(1)</sup>  
(Petroleum Base Fluid)

				Method
Viscometric Properties	25° F	100° F	150° F	
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
5,000 psig				MATLAB 340
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F.	7.68			
Viscosity, centistokes, at 210° F.	2.23			ASTM D-445
0 psig				
Viscosity Slope, ASTM	0.782			
Lubricating Ability				Fed. Method 6503 (modified)
4-Ball Wear Test, 30 min, 50° C., 52100 steel, average scar dia., mm:				-
1 kg				-
3 kg				-
5 kg				-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days				ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

					Method
<u>Corrosion Protection (Cont)</u>					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Brazing Alloy -					-
Steel, 1004					-
Aluminum QQ-A-250-11 -					-
Bronze					-
Aluminum QQ-A-250-4b -					-
Steel, 1009					-
20,000 PSIG Stirred Corrosion					See Chapter 2
Test, weight change, mg					Test C-4
Insulated Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Brazing Alloy					-
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11					-
Aluminum, QQ-A-250-4b -					-
Copper-Nickel (70-30)					-
Monel-Bronze					-
Stainless Steel (316) -					-
Phosphor-Bronze					-
Silver Base Brazing Alloy -					-
Steel, 1009					-
Aluminum, QQ-A-250-11 -					-
Bronze					-
Aluminum, QQ-A-250-4b -					-
Steel, 1009					-
Pump Test					
Average Weight Loss, mg					Proposed military specification for sea-water emulsifying oils
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					
Copper					-
Aluminum					-
Steel, galvanized					-
Steel, 1009					-
Silver Base Brazing Alloy					-
Dielectric Properties					
Resistivity, °F, ohm-cm:					ASTM D-1169 (modified). See Chapter 2. Test E-1
As-Received					Chapter 2 Test E-5
With Sea-Water Contamination:					-
0.1% by volume					-
0.5% by volume					-
2.0% by volume					-
With Carbon Contamination:					Chapter 2 Test E-6
0.1% wt/vol.					-
0.2% wt/vol.					-
0.5% wt/vol.					-

				Method
<u>Dielectric Properties (Cont.)</u>				
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				See Chapter 2 Test E-7
Not filtered				-
Filtered				-
Solids generated, gram				-
Dissipation Factor, %				See Chapter 2 Test E-2
As-Received				See Chapter 2 Test E-5
With Sea-Water Contamination:				-
0.1% by volume				See Chapter 2 Test E-6
0.5% by volume				-
2.0% by volume				-
With Carbon Contamination:				-
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				-
Dielectric Breakdown Voltage, 0.05-inch gap, °F, kV				ASTM D-877 (modified). See Chapter 2, Test E-3
As received				See Chapter 2 Test E-5
With sea-water contamination:				-
0.1% by volume				See Chapter 2 Test E-6
0.5% by volume				-
2.0% by volume				-
With carbon contamination:				-
0.10% wt/vol.				-
0.25% wt/vol.				-
0.50% wt/vol.				-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-
Not filtered				-
Filtered				-
Solids generated, gram				-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				See Chapter 2 Test E-3
Number of tests				-
Operations to failure (range)				-
<u>Emulsion Stability</u>				ASTM D-1401
Paddle Test, after 1-hour set- tling:				-
Oil, ml				-
Emulsion, ml				-
Water, ml				-
Electric Probe Test, time for water separation, min				See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>				See Chapter 2 Test C-3
Butyl				-
Buna N				-
Viton B				-
Ethylene-Propylene				-
Tetrafluoroethylene (Teflon)				-
Neoprene				-
Thickol				-
Silicone				-
Fluorosilicone				-

<u>Volatility</u>		<u>Petroleum</u>			<u>Method</u>
<u>Toxicity</u>					-
<u>Density, grams/cubic centimeter, at:</u>	32° F	100° F	140° F		
0 psig					See NSRDL Annapolis Report MATLAB 50
4,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
14,000 psig					
20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, at:</u>	32° F	100° F	140° F		
0 psig					See NSRDL Annapolis Report MATLAB 50
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-147
Oxidation Stability Test, 250° F					Fed. Method 170
Hydrolytic Stability Test					Military specification MIL-H-19407B
Specimen change, mg					-
Specimen appearance					-
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
<u>Fire Resistance</u>					
Flash Point, °F	530				ASTM D-70
Fire Point, °F					ASTM D-28
Autogenous Ignition Temperature, °F					ASTM D-210
High-Pressure Spray Combustor					See MEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Four Point, °F	+15				ASTM D-27
Foaming Tendency, 75° F					ASTM D-802
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-774
Water Content, % by weight					ASTM D-1744
Neutrality, qualitative					Fed. Method 111
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-508
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-508
Color					ASTM D-152
Cost \$/gal		available from supplier			-
Availability		proprietary			-

Determinations made to atmospheric pressure, unless noted.

Fluid Code L

Suggested Uses and Possible Limitations

Fluid Code L is a silicone oil containing an additive for improving lubrication. Laboratory wear measurements show that the additive has improved the lubricity when compared to a silicone of the same viscosity. However, the wear tests indicate that the lubricity of Code L is still not suitable for a motor or gear lubricant under deep submergence conditions. It affords no corrosion protection, and it is extremely flammable. Its initial dielectric properties are good. Because this product is a slight modification of MIL-S-21568A, 1-cs fluid, it should be a good second choice to the latter product for all electrical applications other than motors.

Fluid Code L(1)  
(Silicone Base Fluid)

Viscometric Properties				Method
Viscosity, centistokes, at:	55° F	100° F	150° F	
0 psig				See NSRDI, Annapolis Report
3,000 psig				MatLab™
5,000 psig				-
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F,	0.76			
Viscosity, centistokes, at 150° F,	0.44			ASTM D-44
0 psig				
Viscosity Slope, ASTM	-			
Lubricating Ability				
4-Ball Wear Test, 10 min, 80° C, 52100 steel, average scar dia., mm:	1% Synthetic Seawater		Pry	
1 kg	-	-		
3 kg	-	-		
5 kg	0.55	-		
15 kg	0.78	-		
30 min, 50° C, 52100 steel, 1 kg	0.26	0.40		
60 min, 50° C, 52100 steel, 1 kg	0.30	0.45		
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Fail			ASTM D-661
On-Off Rust Test, 50% seawater, 140° F, 30 days				See Chapter 7 Test C-1
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 7 Test C-1
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 7 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

Corrosion Protection (Cont.)					
Method					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1004	-				
Aluminum QQ-A-250-11 -	-				
Bronze	-				
Aluminum QQ-A-250-4b -	-				
Steel, 1009	-				
20,000 PSIG Stirred Corrosion					
Test, weight change, mg					
Insulated Specimens:					
Copper	-				
Stainless Steel, 316	-				
Copper-Nickel (70-30)	-				
Aluminum, QQ-A-250-4b	-				
Phosphor-Bronze	-				
Steel, galvanized	-				
Steel, 1009	-				
Aluminum, QQ-A-250-11	-				
Bronze	-				
Monel	-				
Silver Base Brazing Alloy	-				
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-250-11	-				
Aluminum, QQ-A-250-4b -	-				
Copper-Nickel (70-30)	-				
Monel-Bronze	-				
Stainless Steel (316) -	-				
Phosphor-Bronze	-				
Silver Base Brazing Alloy -	-				
Steel, 1004	-				
Aluminum, QQ-A-250-11 -	-				
Bronze	-				
Aluminum, QQ-A-250-4b -	-				
Steel, 1009	-				
Pump Test					
Average Weight Loss, mg					
Steel Gears					
Bronze Bushings					
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					
Copper	-				
Aluminum	-				
Steel, galvanized	-				
Steel, 1009	-				
Silver Base Brazing Alloy	-				
Dielectric Properties					
Resistivity, 76 °F, ohm-cm:					
As-Received					
With Sea-Water Contamination:	5.0x10 <sup>11</sup>				
0.1% by volume	-				
0.5% by volume	-				
2.0% by volume	-				
With Carbon Contamination:					
0.1% wt/vol.	-				
0.25% wt/vol.	-				
0.5% wt/vol.	-				

See Chapter 2  
Test C-4

Proposed military  
specification for  
sea-water emulsi-  
fying oils

ASTM D-1169 (mod-  
ified). See Chap-  
ter 2. Test E-1

Chapter 2

- Test E-5

-

-

Chapter 2

- Test E-6

-

-

Dielectric Properties (C nt)		Method				
After 10,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						See Chapter 2 Test E-7
Not filtered						-
Filtered						-
Solids generated, gram						-
Dissipation Factor, 76 °F, %						See Chapter 2 Test E-2
As-Received						See Chapter 2 Test E-5
With Sea-Water Contamination:						-
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With Carbon Contamination:						See Chapter 2 Test E-6
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						-
Dielectric Breakdown Voltage, 0.05-inch gap, 76 °F, kv	26.2					ASTM D-877 (modified). See Chapter 2, Test E-3
As received						See Chapter 2 Test E-5
With sea-water contamination:						-
0.1% by volume						-
0.5% by volume						-
2.0% by volume						-
With carbon contamination:						See Chapter 2 Test E-6
0.10% wt/vol.						-
0.25% wt/vol.						-
0.50% wt/vol.						-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load						-
Not filtered						-
Filtered						-
Solids generated, gram						-
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F						See Chapter 2 Test E-8
Number of tests						-
Operations to failure (range)						-
<u>Emulsion Stability</u>						
Paddle Test, after 1-hour set- tling:						ASTM D-1401
Oil, ml	40					-
Emulsion, ml	0					-
Water, ml	40					-
Electric Probe Test, time for water separation, min						See Chapter 2 Test E-4
<u>Material Compatibility Static 20KPSI</u>						See Chapter 2 Test C-3
Butyl						-
Buna N						-
Viton B						-
Ethylene-Propylene						-
Tetrafluoroethylene (Teflon)						-
Neoprene						-
Thiokol						-
Silicone						-
Fluorosilicone						-

					Method
<u>Volatility</u>					-
<u>Toxicity</u>		Silicone			-
<u>Density, grams/cubic centimeter, at:</u>	35° F	100° F	150° F		See NSRDL Annapolis Report MATLAB 350
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Isothermal Compressibility, volume decrease, %, at:</u>	35° F	100° F	150° F		See NSRDL Annapolis Report MATLAB 350
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
<u>Chemical Stability</u>					
Oxidation Stability Test, 203° F, hours to failure					ASTM D-943
Oxidation Stability Test, 250° F					Fed. Method 5308
Hydrolytic Stability Test					Military specification MIL-H-19457B
Specimen change, mg					-
Specimen appearance					-
Fluid acid number increase, mg KOH/gram fluid					-
Water acidity, mg KOH					-
Insolubles, %					-
Thermal Stability Test					-
<u>Fire Resistance</u>					
Flash Point, °F					ASTM D-92
Fire Point, °F					ASTM D-92
Autogeneous Ignition Temperature, °F					ASTM D-2155
High-Pressure Spray Combustor					See MEL Report 51/66 of March 1967
Minimum spontaneous ignition temperature, °F					-
Minimum reaction temperature, °F					-
No indication of fire, °F					-
Maximum pressure change, psi					-
Lowest temperature of maximum pressure change, °F					-
Temperature range explored, °F					-
<u>Miscellaneous Properties</u>					
Pour Point, °F					ASTM D-97
Foaming Tendency, 75° F					ASTM D-892
Foam after 5-minute aeration, ml					-
Time out, minutes					-
Foam after 10-minute settling, ml					-
Neutralization Number, mg KOH/gram					ASTM D-974
Water Content, % by weight					ASTM D-1744
Neutrality, qualitative					Fed. Method 5101
Contamination					-
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-598
25-100 micrometers					-
100-500 micrometers					-
over 500 micrometers					-
particles over 250 micrometers except fibers (length ten times diameter)					-
Gravimetric Value, mg/100 ml					SAE Method ARP-785
Color					ASTM D-1500
Cost \$/gal		available from supplier			-
Availability		proprietary			-

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Fluid Code M

Suggested Uses and Possible Limitations

Fluid Code M has a low viscosity which would indicate that it may be suitable for special requirements at great depths. Its wear test is rather good, indicating the possibility of favorable lubrication properties. It provides some corrosion inhibition. It has a low resistivity and a high dissipation factor, making it questionable for any electrical application at deep ocean pressure. It is highly flammable.

Fluid Code M<sup>(1)</sup>  
(Petroleum Base Fluid)

				Method
Viscometric Properties	75° F	100° F	150° F	
Viscosity, centistokes, at:				
0 psig				See NSRDL
3,000 psig				Annapolis Report
5,000 psig				MATLAB 350
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
Viscosity, centistokes, at 100° F,	3.08			
Viscosity, centistokes, at 210° F,	1.20			ASTM D-445
0 psig				-
Viscosity Slope, ASTM	0.865			
Lubricating Ability				
4-Ball Wear Test, 60 min, 80° C, 52100 steel, average scar dia., mm:				Fed. Method 6905 (modified)
40 kg	0.75			-
Corrosion Protection				
Stirred Rust Test, 10% seawater, 140° F, 2 days	Pass			ASTM D-665
On-Off Rust Test, 50% seawater, 140° F, 30 days	Fail			See Chapter 2 Test C-5
Ambient Pressure, coupon stirred, corrosion test, weight change, mg				See Chapter 2 Test C-1
Copper	-14.8			-
Stainless Steel, 316	+ 0.3			-
Copper-Nickel (70-30)	- 1.1			-
Aluminum, QQ-A-250-4b	+ 0.5			-
Phosphor-Bronze	- 9.8			-
Steel, galvanized	- 6.8			-
Steel, 1009	+ 0.2			-
Aluminum, QQ-A-250-11	- 0.6			-
Bronze	- 7.9			-
Monel	- 1.5			-
Silver Base Brazing Alloy	- 6.7			-
20,000 PSIG Pressure-Cycled Corrosion Test (1% seawater), weight change, mg				See Chapter 2 Test C-2
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-

				Method
<b>Corrosion Protection (Cont)</b>				
Electrically Coupled Specimens:				-
Copper-Aluminum, QQ-A-250-11				-
Aluminum, QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Brazing Alloy -				-
Steel, 1004				-
Aluminum QQ-A-250-11 -				-
Bronze				-
Aluminum QQ-A-250-4b -				-
Steel, 1009				-
20,000 PSIG Stirred Corrosion				See Chapter 2 Test C-4
Test, weight change, mg				
Insulated Specimens:				
Copper				-
Stainless Steel, 316				-
Copper-Nickel (70-30)				-
Aluminum, QQ-A-250-4b				-
Phosphor-Bronze				-
Steel, galvanized				-
Steel, 1009				-
Aluminum, QQ-A-250-11				-
Bronze				-
Monel				-
Silver Base Brazing Alloy				-
Electrically Coupled Specimens:				-
Copper-Aluminum, QQ-A-250-11				-
Aluminum, QQ-A-250-4b -				-
Copper-Nickel (70-30)				-
Monel-Bronze				-
Stainless Steel (316) -				-
Phosphor-Bronze				-
Silver Base Brazing Alloy -				-
Steel, 1009				-
Aluminum, QQ-A-250-11 -				-
Bronze				-
Aluminum, QQ-A-250-4b -				-
Steel, 1009				-
Pump Test				
Average Weight Loss, mg				
Steel Gears				
Bronze Bushings				
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>				
Copper				-
Aluminum				-
Steel, galvanized				-
Steel, 1009				-
Silver Base Brazing Alloy				-
Dielectric Properties				
Resistivity, 77° F. ohm-cm:	2.8x10 <sup>3</sup>			
As-Received				
With Sea-Water Contamination:				
0.1% by volume				
0.5% by volume				
2.0% by volume				
With Carbon Contamination:				
0.1% wt/vol.				
0.25% wt/vol.				
0.5% wt/vol.				

Dielectric Properties (Cont.)		Method			
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load Not filtered Filtered Solids generated, gram					See Chapter 2 Test E-7
Dissipation Factor, 77 °F, %					-
As-Received					-
With Sea-Water Contamination: 0.1% by volume 0.5% by volume 2.0% by volume	>60				See Chapter 2 Test E-2 See Chapter 2 Test E-5
With Carbon Contamination: 0.10% wt/vol. 0.25% wt/vol. 0.50% wt/vol.					-
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load Not filtered Filtered Solids generated, gram					See Chapter 2 Test E-6
Dielectric Breakdown Voltage, 0.05-inch gap, 77 °F, kv					-
As received	20.6				ASTM D-877 (modified). See Chapter 2, Test E-3
With sea-water contamination: 0.1% by volume 0.5% by volume 2.0% by volume					See Chapter 2 Test E-5
With carbon contamination: 0.10% wt/vol. 0.25% wt/vol. 0.50% wt/vol.					-
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load Not filtered Filtered Solids generated, gram					See Chapter 2 Test E-6
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F Number of tests Operations to failure (range)					-
Emulsion Stability					-
Paddle Test, after 1-hour set- tling: Oil, ml Emulsion, ml Water, ml	32 23 25				ASTM D-1401
Electric Probe Test, time for water separation, min					-
Material Compatibility Static 20KPSI					-
Rubber swell, %, 150° F, 168 hr.					See Chapter 2 Test E-4
Butyl					See Chapter 2 Test C-3
Buna N - L stock	21.1				-
Buna N - H stock	8.1				-
Viton B					-
Ethylene-Propylene					-
Tetrafluoroethylene (Teflon)					-
Neoprene					-
Thickol					-
Silicone					-
Fluorosilicone					-

\* Based on atmospheric pressure data.

Volatility Toxicity		Autogeuus			Method
Density, grams/cubic centimeter, at:	35° F	100° F	150° F		
0 psig					See NSRDL Annapolis Report NATLAB 350
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
Isothermal Compressibility, volume decrease, %, at:	35° F	100° F	150° F		See NSRDL Annapolis Report NATLAB 350
0 psig					
3,000 psig					
5,000 psig					
8,000 psig					
10,000 psig					
15,000 psig					
20,000 psig					
Chemical Stability					
Oxidation Stability Test, 205° F, hours to failure	Satisfactory				ASTM D-942
Oxidation Stability Test, 250° F					
Hydrolytic Stability Test					
Specimen change, mg					
Specimen appearance					
Fluid acid number increase, mg KOH/gram fluid					
Water acidity, mg KOH					
Insolubles, %					
Thermal Stability Test					
Fire Resistance					
Flash Point, °F	215	220			ASTM D-32
Fire Point, °F					ASTM D-32
Autogenous Ignition Temperature, °F					ASTM D-215
High-Pressure Spray Combustor					See MEL Report 31/66 of March 1967
Minimum spontaneous ignition temperature, °F					
Minimum reaction temperature, °F					
No indication of fire, °F					
Maximum pressure change, psi					
Lowest temperature of maximum pressure change, °F					
Temperature range explored, °F					
Miscellaneous Properties					
Pour Point, °F	<90				ASTM D-77
Foaming Tendency, 75° F					ASTM D-697
Foam after 5-minute aeration, "					
Time out, minutes					
Foam after 10-minute settling, ml					
Neutralization Number, mg KOH/gram	0.03				ASTM D-974
Water Content, % by weight	0.035				ASTM D-1744
Neutrality, qualitative					Fed. Method 101
Contamination					
Number and size of particles and fibers in 100-ml fluid					SAE Method ARP-508
25-100 micrometers					
100-500 micrometers					
over 500 micrometers					
particles over 250 micrometers except fibers (length ten times diameter)					
Gravimetric Value, mg/100 ml					SAE Method ARP-78
Specific gravity at 70/60 °F	0.856				ASTM D-1298
Color					ASTM D-1500
Cost \$/gal		available from supplier			
Availability		proprietary			

<sup>1</sup>Determinations made at atmospheric pressure, unless noted.

Fluid Code N

Suggested Uses and Possible Limitations

Fluid Code N is a sea-water-compatible/water-glycol-type hydraulic fluid and lubricant. Its viscosity is high, but since it has a water base it is possible that pressure would increase the viscosity by only a small amount. It provides fair lubrication for all conditions except rolling contact. It provides some corrosion protection. It will be unsuitable for any electric application at deep ocean pressure since its water base gives it unsuitable dielectric properties. It is fire resistant in spite of its low flash point since it will cease to burn when the source of ignition is removed.

Fluid Code 5(1)  
(Water-Glycol Type Fluid)

Viscometric Properties		32° F	100° F	150° F	Method
Viscosity, centistokes, at:					
0 psig					See NSRDL
3,000 psig					Annapolis Research
5,000 psig					NATLAB 550
8,000 psig					-
10,000 psig					-
15,000 psig					-
20,000 psig					
Viscosity, centistokes, at 100° F.	67.3				
Viscosity, centistokes, at 150° F.	28				ASTM D-441
0 psig					
Viscosity Slope, ASTM	0.533				-
Lubricating Ability					
4-Ball Wear Test, 30 min, 50° C.,					See Method 6711
52100 steel, average scar dia.,					(modified)
mm:					
1 kg					-
3 kg					-
15 kg		0.81			-
Corrosion Protection					
Stirred Rust Test, 10% seawater,					ASTM D-670
140° F, 2 days	Pass				
On-Off Rust Test, 50% seawater,					See Chapter 2
140° F, 30 days	Fail				Test C-5
Ambient Pressure, coupon					See Chapter 2
stirred, corrosion test, weight					Test C-1
change, mg					
Copper	+ 3.0				
Stainless Steel, 316	+ 0.5				-
Copper-Nickel (70-30)	+ 1.3				-
Aluminum, QQ-A-250-4b	+ 1.4				-
Phosphor-Bronze	- 3.3				-
Steel, galvanized	- 6.0				-
Steel, 1009	-452.4				-
Aluminum, QQ-A-250-11	- 0.7				-
Bronze	+ 3.2				-
Monel	+ 1.1				-
Silver Base Braze Alloy	- 9.2				-
20,000 PSIG Pressure-Cycled					See Chapter 2
Corrosion Test (1% seawater),					Test C-2
weight change, mg					
Inertized Specimens:					
Copper					-
Stainless Steel, 316					-
Copper-Nickel (70-30)					-
Aluminum, QQ-A-250-4b					-
Phosphor-Bronze					-
Steel, galvanized					-
Steel, 1009					-
Aluminum, QQ-A-250-11					-
Bronze					-
Monel					-
Silver Base Braze Alloy					-

Corrosion Protection (Cont.)					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-210-11					
Aluminum QQ-A-210-4b -					
Copper-Nickel (70-30)					
Monel-Bronze					
Stainless Steel ('16) -					
Phosphor-Bronze					
Silver Base Brazeing Alloy -					
Steel, 1004					
Aluminum QQ-A-210-11 -					
Bronze					
Aluminum QQ-A-210-4b -					
Steel, 1009					
20,000 PSIG Stressed Corrosion					
Test, weight change, mg					
Insulated Specimens:					
Copper					
Stainless Steel, '16					
Copper-Nickel (70-30)					
Aluminum, QQ-A-210-4b					
Phosphor-Bronze					
Steel, galvanized					
Steel, 1004					
Aluminum, QQ-A-210-11					
Bronze					
Monel					
Silver Base Brazeing Alloy					
Electrically Coupled Specimens:					
Copper-Aluminum, QQ-A-210-11					
Aluminum, QQ-A-210-4b -					
Copper-Nickel (70-30)					
Monel-Bronze					
Stainless Steel ('16) -					
Phosphor-Bronze					
Silver Base Brazeing Alloy -					
Steel, 1004					
Aluminum, QQ-A-210-11 -					
Bronze					
Aluminum, QQ-A-210-4b -					
Steel, 1009					
Pump Test					
Average Weight Loss, mg					
Steel Gears	8.1				
Bronze Bushings	35.1				
Corrosion Coupons, weight loss, each, mg/cm <sup>2</sup>					
Copper					
Aluminum					
Steel, galvanized					
Steel, 1009					
Silver Base Brazeing Alloy					
Dielectric Properties					
Resistivity, °F, ohm-cm:					
As-Received					
With Sea-Water Contamination:					
0.1% by volume					
0.5% by volume					
2.0% by volume					
With Carbon Contamination:					
0.1% wt/vol.					
0.25% wt/vol.					
0.5% wt/vol.					

See Chapter 7  
Test E-6

Proposed military  
specification for  
sea-water containing  
fuelling oils

ASTM D-1169 (not  
classified). See Chapter  
7, Test E-1  
Chapter 7  
Test E-2

Chapter 7  
Test E-6

				Method	
<u>Dielectric Properties (Cont.)</u>					
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				See Chapter 1 Test E-7	
Not filtered				-	
Filtered				-	
Solids generated, gram				-	
Dissipation Factor, °F, t				See Chapter 1 Test E-1	
As-Received				See Chapter 1 Test E-1	
With Sea-Water Contamination:				-	
0.1% by volume				-	
0.5% by volume				-	
2.0% by volume				-	
With Carbon Contamination:				See Chapter 2 Test E-4	
0.10% wt/vol.				-	
0.25% wt/vol.				-	
0.50% wt/vol.				-	
After 50,000 Electric Arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-	
Not filtered				-	
Filtered				-	
Solids generated, gram				-	
Dielectric Breakdown Voltage, 0.05-inch gap, °F, kv				ASTM D-877 (modi- fied). See Chap- ter 2, Test E-5	
As received				See Chapter 2 Test E-5	
With sea-water contamination:				-	
0.1% by volume				-	
0.5% by volume				-	
2.0% by volume				-	
With carbon contamination:				See Chapter 2 Test E-6	
0.10% wt/vol.				-	
0.25% wt/vol.				-	
0.50% wt/vol.				-	
After 50,000 electric arcs (makes and breaks) at 90 volts, 10 amperes, resistive load				-	
Not filtered				-	
Filtered				-	
Solids generated, gram				-	
Contact Life, silver-cadmium, 50 volts, 10 amperes, resistive load, 6000 psi, 65°-85° F				See Chapter 2 Test E-3	
Number of tests				-	
Operations to failure (ran.)				-	
<u>Emulsion Stability</u>					
Paddle Test, after 1-hour set- tling:				ASTM D-1401	
Oil, ml				-	
Emulsion, ml				-	
Water, ml				-	
Electric Probe Test, time for water separation, min				See Chapter 1 Test E-4	
<u>Material Compatibility Static CCRPSI</u>				See Chapter 1 Test E-3	
Butyl	Good			-	
Buna N	Good			-	
Viton B	Good			-	
Ethylene-Propylene	Good			-	
Tetrafluoroethylene (Teflon)	Good			-	
Neoprene	Fair-Good			-	
Thickol	-			-	
Silicone	Poor			-	
Dyrosilicone	POOR			-	

\* Based on atmospheric pressure data

<u>Volatility</u> <u>Toxicity</u>	<u>Boiling Water Glycol</u>	<u>100° F</u>	<u>150° F</u>	<u>Method</u>
<u>Density, grams/cubic centimeter, at:</u>				
0 psig	35° F	100° F	150° F	-
3,000 psig				-
5,000 psig				-
8,000 psig				-
10,000 psig				-
15,000 psig				-
20,000 psig				-
<u>Isothermal Compressibility, volume decrease, %, at:</u>				
0 psig	35° F	100° F	150° F	
3,000 psig				
5,000 psig				
8,000 psig				
10,000 psig				
15,000 psig				
20,000 psig				
<u>Chemical Stability</u>				
<u>Oxidation Stability Test, 203° F, hours to failure</u>				ASTM D-947
<u>Oxidation Stability Test, 250° F</u>				
<u>Hydrolytic Stability Test</u>				
Specimen change, mg	0.02			
Specimen appearance	Satisfactory			
Fluid acidity pH	9.8			
Insolubles, %	nil			
<u>Thermal Stability Test</u>				
<u>Fire Resistance</u>				
Flash Point, °F	265			ASTM D-92
Fire Point, °F	270			ASTM D-93
Autogeneous Ignition Temperature, °F	825			ASTM D-2155
<u>High-Pressure Spray Combustor</u>				
Minimum spontaneous ignition temperature, °F	500			See MEL Report 51/66 of March 1967
Minimum reaction temperature, °F	460			-
No indication of fire, °F	450			-
Maximum pressure change, psi	200			-
Lowest temperature of maximum pressure change, °F	560			-
Temperature range explored, °F	450-560			-
<u>Miscellaneous Properties</u>				
Pour Point, °F	-20			ASTM D-47
Foaming Tendency, 75° F				ASTM D-897
Foam after 5-minute aeration, ml	280			-
Time out, minutes	4			-
Foam after 10-minute settling, ml	0			-
Neutralization Number, mg KOH/gram				ASTM D-1774
Water Content, % by weight				ASTM D-1744
Neutrality, qualitative				Fed. Method F-101
Contamination				-
Number and size of particles and fibers in 100-ml fluid				SAE Method ARP- 698
25-100 micrometers				-
100-500 micrometers				-
over 500 micrometers				-
particles over 250 microm- eters except fibers (length ten times diameter)				-
Gravimetric Value, mg/100 ml				SAE Method ARP- 734
Color				ASTM D-1100
Cost, \$/pi		Available from supplier		-
Availability		Proprietary		-

\*Determinations made at atmospheric pressure, unless noted.

Fluid Code N

<u>Material Compatibility with:</u>		<u>Method</u>
Natural Rubber	Fair	See Chapter 2
Polyurethane	Poor	Test C-3

\* Based on atmospheric pressure data.

111-182

## BIBLIOGRAPHY

Adamczak, R. L., R. J. Benzing, and H. Schwenker, "Proceedings of the AFML Hydraulic Fluids Conference," Air Force Materials Lab., Air Force Systems Command, Wright-Patterson Air Force Base, Tech Rept AFML-TR-67-369, AD827561, 1967

Anderson, R. E., "Compatible Non-Metallic Environmental Materials for Water-Glycol Type Fluids," MEL R&D Rept 95684E, 1963

Appeldoorn, J. K., E. H. Okrent, and W. Philipoff, "Viscosity and Elasticity at High Pressure and High Rates of Shear," Proceedings of the American Petroleum Institute, Vol. 42 (III), 1963, p. 163

"ASTM Standards," Parts 17, 18, and 29, 1969

Brown, C. L., "Fluid Structural Factors Versus Fire Resistance," U. S. Navy Marine Engineering Lab. R&D Rept 95 648C, 1962

Chaffee, W. E., "Isothermal Compressibility for Seven Fluids," Materials Lab., NAVSHIPYD SFRAN Rept 297-68, 1968

Cornish, T. N., "Compatible Non-Metallic Environmental Materials for Triaryl Phosphate Type Fluids," MEL R&D Rept 81116A, 1963

Deane, T. N., "Criteria for Choosing Hydraulic Fluids," Lubrication Engineering, Vol. 23, 1967, p. 498

Deane, T. N., "The Effect of Contamination on Fluids and the Effect of Fluids on Contamination," Proceedings of Aerospace Fluid Power Systems and Equipment Conference, SAE Committee A6, May 1965

"Design Considerations for Submarine Hydraulic Systems," NAVSHIPYD SFRAN Rept 1-62, 1962

"Determination of the Shear Stability of Non-Newtonian Liquids," ASTM Special Technical Publication 182, 1955

Evans, A. P., "Fluids for External Hydraulic Systems," U. S. Navy Marine Engineering Lab. R&D Rept 95 680J, 1964

Fainman, M. Z., and W. B. MacKenzie, "The Characteristics and Performance of Specification MIL-H-5606 Hydraulic Fluid," Lubrication Engineering, Vol. 22, 1966, p. 234

"Federal Test Methods Standard 791a," GSA, Washington, D. C. (latest modification)

Fitch, E. C., Fluid Power and Control Systems, New York, McGraw-Hill, Inc., 1966

"General Environmental Requirements for Deep Submersible Vehicles and Submarines," Society of Automotive Engineers, Hydrospace Information Rept AIR 1063, 1968

Gunderson, R. C., and A. W. Hart, Synthetic Lubricants,  
New York, Reinhold Publishing Co., 1962

Hatton, Roger E., Introduction to Hydraulic Fluids, New York,  
Reinhold Publishing Co., 1962

King, H. F., and N. Glassman, "Lubrication in a Marine  
Environment," The Institute of Mechanical Engineers, Proceedings  
Paper No. 34, Vol. 182, Part 3A, 1967-1968, pp. 520-530

Klaus, E. E., and M. R. Fenske, "Some Viscosity Shear Char-  
acteristics of Lubricants," Lubrication Engineering, Vol. 11,  
1955, p. 100

Klaus, E. E., et al, "A Study of Tricresyl Phosphate as an  
Additive for Boundary Lubrication," ASLE Transactions, Vol. 11,  
1968, p. 155

Klaus, E. E., et al, "Fluid, Lubricants, Fuels and Related  
Materials," Air Force Materials Lab., Air Force Systems Com-  
mand, Wright-Patterson Air Force Base, Technical Rept AFML-  
TR-67-107 (and all preceding reports), 1967

Knapp, G. G., and H. D. Orloff, "Improved Lubricating Oil  
Antioxidants," Industrial and Engineering Chemistry, Vol. 53,  
1961, p. 65

Lancaster, W. J., "Hydraulic Fluids for Deep Submersibles,"  
Lockheed Missiles and Space Co., Sunnyvale, Calif., LMSC  
DO18772, 1968

Marzani, J. A., and R. W. McQuaid, "A Method for Defining  
Fire Resistance of Hydraulic Fluids," MEL R&D Rept 31/66, 1967

Marzani, J. A., and R. W. McQuaid, "Effect of Water Upon  
Hydraulic Fluid Flood Lubricated Ball Bearing Fatigue Life  
(DOT Fluids)," NAVSHIPRANLAE Annapolis Rept MATLAB 300, 1969

McQuaid, R. W., "Hydraulic Fluids for Deep Submergence,"  
SAE Conference Proceedings, Aerospace Systems Conference, 1967

McQuaid, R. W., and K. H. Keller, "Fluids and Lubricants for  
Submersible Electrical and Mechanical Systems," American Insti-  
tute of Chemical Engineers, Annual Meeting, Paper 26b, 1969

Merritt, H. E., Hydraulic Control Systems, New York, John  
Wiley and Sons, 1967

Messina, J., et al, "Evaluation of Long Chain Phosphorus  
Compounds as Lubricity Additives," ASLE Transactions, Vol. 3,  
1960, p. 48

Messina, J., and A. Mertwuy, "Inorganic Salts in Mahogany  
Sulfonates and Their Effect on Petroleum Hydraulic Fluids,"  
Lubrication Engineering, Vol. 23, 1967, p. 46

Miles, D. O., A. S. Hamamoto, and G. C. Knollman, "Visco-  
elastic Shear and Compressional Properties of Hydraulic Fluids  
in Deep Ocean Environments," Lockheed Palo Alto Research Lab.,  
Lockheed Missiles and Space Co., Palo Alto, Calif., LMSC 6-96-  
68-5, 1968

Murphy, C. M., J. B. Romans, and W. A. Zisman, "Viscosity and Densities of Lubricating Fluids from 40°F to 700°F," ASLE Transactions, 1949, p. 561

Philipoff, W., "Viscoelasticity of Polymer Solutions at High Pressure and Ultrasonic Frequencies," Journal of Applied Physics, Vol. 34, 1963, p. 1507

Pippenger, J. J., and T. G. Hicks, Industrial Hydraulics, New York, McGraw-Hill Book Co., 1962

"Pressure-Viscosity Report," Vols. 1 and 2, American Society of Mechanical Engineers, 1953

"Procedure for the Determination of Particulate Contamination of Hydraulic Fluids by the Particle Count Method," Society of Automotive Engineers, Aerospace Recommended Practice ARP 598, 1960

"Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure," Society of Automotive Engineers, Aerospace Recommended Practice ARP 785, 1963

Ravner, H., E. F. Russ, and C. O. Tammons, "Antioxidant Action of Metals and Metal Organic Salts Fluoroesters and Polyphenyl Ethers," Journal of Chemical Engineering Data, Vol. 8, 1963, p. 591

Schatzberg, Paul, "Solubilities of Water in Several Normal Alkanes from C<sub>7</sub> to C<sub>16</sub>," Journal of Physical Chemistry, Vol. 67, 1963, p. 776

Schatzberg, P., and I. M. Felsen, "Effects of Water and Oxygen During Rolling Contact Lubrication," Wear, Vol. 12, 1969, p. 331

Schatzberg, P., and I. M. Felsen, "Influence of Water on Fatigue Failure Location," ASME Paper 68, Lub 11, 1968

Snead, Messina, and Gisser, "Structural Effects of Aryl-stearic Acids as Combination Oxidation and Rust Inhibitors," Industrial and Engineering Chemistry, Product Research and Development, Vol. 5, 1966, p. 222

"Status of Research on Lubricants Friction and Wear," NRL Rept 6466, 1967

Stewart, W. T., and F. A. Stuart, "Lubricating Oil Additives," Advances in Petroleum Chemistry and Refining, Vol. VII, New York, Interscience, 1963

"Symposium on Hydraulic Fluids," ASTM Special Technical Publication 267, 1960

Tichy, J. A., and W. O. Winer, "A Correlation of Bulk Moduli and P-V-T Data for Silicone Fluids at Pressures Up to 500,000 psig," ASLE Transactions, Vol. 11, 1968, p. 1338

Ventriglio, D. R., C. L. Brown, and R. W. McQuaid, "Viscosity of Seven Fluids at Ambient Deep Ocean Temperatures and Pressures," NAVSHIPRANLAB Annapolis Rept MTLAB 350, 1969

"Viscosity," Lubrication, Vol. 52, No. 3, Texaco, Inc., New York, 1966

Wright, H. A., "Prediction of Bulk Moduli and Pressure - Volume-Temperature Data for Petroleum Oils," ASLE Transactions, Vol. 10, 1967, p. 349

Wyllie, D., and A. W. Morgan, "Prevention of Corrosion in Glycerol-Water Hydraulic Fluids," Journal of Applied Chemistry, London, Vol. 15, 1965, p. 289

Yeaple, F. D. (ed.), Hydraulic and Pneumatic Power and Control, New York, McGraw-Hill Book Co., Inc., 1966

Zabetakis, M. G., et al, "Research on the Flammability Characteristics of Aircraft Hydraulic Fluids," WADC-TR-57-151 Supplement, 1958, and Part II, 1959

Zuidema, H. H., The Performance of Lubricating Oil, New York, Reinhold Publishing Co., 1959

#### Additional References Relating to Electrical Properties

Bloomquist, Dick L., "Status Report, Deep Ocean Technology," ANNADIV NAVSHIPRANDCEN Rept MACHLAB 5, Aug 1968

Clark, Frank M., Insulation Materials for Design and Engineering Practice, New York, John Wiley and Sons, Inc.,

Kellenbenz, Carl W., "Electrical Protective and Switching Devices in Fluid Pressure Ambients, Part II: Solid-State Devices," NAVSHIPRANLAB Annapolis Rept ELECLAB 24/69, May 1969

Kellenbenz, Carl W., "Deep Ocean Technology Program, Electrical Solid State Switching Devices, Part II," NAVSHIPRANLAB Annapolis Rept ELECLAB 79/69 (in preparation)

Pocock, Walter E., "Deep Ocean Technology Program, Electrical Protective and Switching Devices in Fluid Pressure Ambients, Part I: Mechanical Switching Devices," NAVSHIPRANLAB Annapolis Rept ELECLAB 23/69, May 1969

Pocock, Walter E., "Deep Ocean Technology Program, Electrical Protective and Switching Devices in Fluid Pressure Ambients: Mechanical Switching Devices," NAVSHIPRANLAB Annapolis Rept ELECLAB 46/69 (in preparation)

Pocock, Walter E., "Quality Control Procedures for General Electric Co. SF 96-1 Silicone Fluid Used as a Compensating Fluid on Navy Submersibles," ANNADIV NAVSHIPRANDCEN Ltr Rept ELECLAB 238/68, 14 Nov 1968

Pocock, Walter E., and J. Tobin, "Electrical Arcing in Insulating Liquids, A Bibliography," NAVSHIPRANLAB Annapolis Tech Note ELECLAB 32/69, June 1969

Tobin, John F., "Deep Ocean Technology Program, Electrical Insulating Materials in Fluid Pressure Ambients," NAVSHIPRANLAB Annapolis Rept ELECLAB 66/69 (in preparation)

Tobin, J., and R. Flaherty, "Status Report of Electric Insulation, Deep Ocean Technology Program," ANNADIV NAVSHIPRANDCEN Rept ELECLAB 246/68, June 1968

USER COMMENT RETURN FORM

---

(date)

From:

To: Deep Ocean Technology Program

Subj: Improvement of Handbook of Fluids and Lubricants for  
Deep Ocean Applications, Suggestions for

1. It is suggested that the handbook could be improved by  
making the following changes:

2. Reasons for suggested changes are:

3. It is further suggested that the handbook could be made  
more useful to users by adding material on the following (indicate  
sources of required information if known):

---

(signature)

(date)

---

(title, organization)

(Return Address)

(Fold so that return address is out, tape, and mail.  
No postage required.)

DEPARTMENT OF THE NAVY  
NAVAL SHIP RESEARCH  
AND DEVELOPMENT LABORATORY  
ANNAPOLIS, MARYLAND 21402

Postage and Fees Paid  
Department of the Navy

OFFICIAL BUSINESS

Commanding Officer  
Naval Ship Research and Development Laboratory  
Annapolis, Maryland 21402

Attn: Deep Ocean Technology Program

-----

-----

Security Classification

UNCLASSIFIED

## DOCUMENT CONTROL DATA - R &amp; D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. SPONSORING ACTIVITY (Expense author)

Naval Ship Research and Development Laboratory, Annapolis, Maryland 21402

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

Handbook of Fluids and Lubricants for Deep Ocean Applications

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Richard W. McQuaid ~~and~~ Charles L. Brown

13 254b.

6. PREPARED DATE

December 1969

7a. APPROVAL NUMBER

0002

7b. NO. OF PGS

64

8. PROJECT

S4636

9. Tasks

12315, 14745

9. ORIGINATOR'S REPORT NUMBER(S)

14 MATLAB-360

10. Work Units

1-821-118-A

10. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

1-723-113-A

11. DISTRIBUTION STATEMENT

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of CDR, NAVSHIPS (SHIPS 03424), Washington, D.C. 20360

12. SPONSORING MILITARY ACTIVITY

NAVSHIPS (SHIPS 03424)

13. ABSTRACT

The critical factors involved in the selection of fluids and lubricants for deep ocean equipment are defined, and methods of determining critical properties are described. The values of critical properties are given for fluids and lubricants as they have been determined or are known from previous literature. Suggestions also are given on the applicability and possible limitations of the fluids and lubricants for deep submergence vehicle use. It is planned to revise and update the contents of this handbook periodically.

(Authors)

404 417



DD FORM 1 NOV. 1973

(PAGE 1)

S/N 0101-807-6801

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Deep ocean Temperatures Pressures Fluids Properties Power Lubrication Shielding						

DD FORM 1473 (BACK)  
(PAGE 2)

UNCLASSIFIED  
Security Classification